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ART. XXXI.—*Distance of the Stars by Doppler's Principle;* by G. W. COLLES, JR.

AMONG the many interesting and important applications of Doppler's principle for finding the velocity of a body in the line of sight or sound, is one which has been apparently little noticed, namely, that to the determination of distance. It is true, however, that this is easily accounted for by the fact that the principle itself is not yet far enough advanced for the application of such a problem. I believe the first mention of it is that made by Fox Talbot, in a paper read before the British Association in 1871, in which he showed how Doppler's principle might be applied to finding the distance of a binary system. Supposing the orbit of each star to be accurately known, in shape and position, let their relative velocities be taken by the spectroscope when the two stars are moving as nearly as possible in the line of sight. Now, since we know the shape of the orbit, we know the *proportionate* velocities of the stars at any point of it; hence, knowing also the *absolute* velocities at one point of the orbit, we can deduce them for the point where each star is moving only across the line of sight. Then, finding the angular velocity at this point, and dividing the computed linear velocity by it, we have the distance of the system. Or otherwise, knowing the actual period of the system, the absolute velocity at any point gives us the true size, or diameter, of the orbit; and dividing this by the angular diameter, we have, as before, the distance of the system.

Talbot's idea was taken up in 1886 by Prof. A. A. Rambaut, now Astronomer Royal of Ireland, and he has quite elaborately

discussed it in two papers published in the *Proceedings of the Royal Irish Academy* and in the *Monthly Notices*, respectively.* It could, of course, be extended to multiple systems, the principal drawback being that it necessitates the knowledge of the inclination of the plane of revolution to the line of sight. Obviously it can not be applied to any single body, unless its exact direction,—that is, the ratio of the components of its motion in and across the line of sight,—be known. In such a case as that of the so-called "runaway star" (1830 Groombridge) this might sometime be ascertained, if the star should ever get far enough so that increase or decrease in its annual angular motion could be measured. In general, however, the limitations of our present knowledge of astronomy seem to preclude this method of finding the distance of particular stars.

The application of Doppler's principle which I had in mind, however, is a very much wider one than any of these.† It is to the problem of finding the mean distance of all the stars, involving the theory of probability, and giving us a more or less reliable idea of the extent of our cosmus.

For the demonstration, suppose a very large number of stars —so large as to be practically infinite—distributed equably over the celestial sphere; that their motions are perfectly at random, and represented by straight lines according to the usual convention; and that the velocity in the line of sight and the proper angular motion of each star are correctly known. Let r be the radius vector drawn from the earth to any star, ϑ and φ the angles of reference of r to a fixed line and a fixed plane passing through that line, respectively; v the line representing the motion of any star and ϑ' and φ' angles of reference similar to ϑ and φ, and of which r is the initial line. The mean value of the projection of v upon r, which we will call $\mathrm{M}(\alpha)$, is, then, *abstracting signs*,

$$\mathrm{M}(\alpha) = \frac{2v\int_0^{\frac{\pi}{2}}\int_0^{2\pi} \cos\vartheta' \sin\vartheta' d\vartheta' \, d\varphi'}{\int_0^{\pi}\int_0^{2\pi} \sin\vartheta' \, d\vartheta' \, d\varphi'} = \frac{2\pi v}{4\pi} = \frac{v}{2}.$$

For it will be seen that, since all directions for r are equally probable, and also all directions for v are equally probable,

* See Proc. Roy. I. Acad., 2nd ser.. vol iv, No. 6, and Month. Not. Roy. Ast. Soc, vol. l, p 302, "On the Parallax of Double Stars."

† Suggested to me by Prof. H. A. Newton. I believe the problem has been previously discussed, but with inaccurate results. The idea must have long been more or less vaguely in the minds of astronomers.

therefore all values for the solid angle $\vartheta'\varphi'$ are equally probable, and the mean projection on r is the same as if r were fixed. Also, it will be seen that v may vary in any way we please, so long as it is not a function of ϑ' or φ'; its value in the result being some function of its particular values. The mean value of the projection of v on a plane perpendicular to r is, in like manner,

$$\mathrm{M}(\beta)=\frac{a\int_0^{\pi}\int_0^{2\pi}\sin^2\Im'\,d\Im'\,d\varphi'}{\int_0^{\pi}\int_0^{2\pi}\sin\Im' d\Im'\,d\varphi'}=\frac{\pi^2 v}{4\pi}=\frac{\pi v}{4},$$

where v has the same value as before. The ratio of the latter mean value to the former is, therefore,

$$\frac{\mathrm{M}(\beta)}{\mathrm{M}(\alpha)}=\frac{v\int_0^{\pi}\int_0^{2\pi}\sin^2\Im'\,d\Im'\,d\varphi'}{2v\int_0^{\frac{\pi}{2}}\int_0^{2\pi}\cos\Im'\sin\Im' d\Im' d\varphi'}=\frac{\pi}{2}.$$

Thus we obtain the ratio of the mean velocity of a star across the line of sight to its mean velocity in the line of sight, supposing the direction and magnitude of its total velocity to be at random, that is, independent of the angles ϑ and φ, or ϑ' and φ'. And if the stars are distributed equably over only one hemisphere (that of which the initial line is the pole, suppose), the above ratio remains the same as before; because one hemisphere is in all respects similar to the other, negative signs having been abstracted. Further, if the stars are distributed equably over *any part* of the celestial sphere, comprised (suppose) between the angles ϑ_1 and ϑ_2, φ_1 and φ_2 (which may be functions of ϑ), the above ratio becomes, remembering that negative values are to be reckoned as positive,

$$\frac{\mathrm{M}(\beta)}{\mathrm{M}(\alpha)}=\frac{\int_{\vartheta_1}^{\vartheta_2}\int_{\phi_1}^{\phi_2}\sin^2\Im' d\Im' d\varphi'}{\int_{\vartheta_1}^{\vartheta_2}\int_{\phi_1}^{\phi_2}\cos\Im'\sin\Im' d\Im' d\varphi'};$$

for it will be seen, on consideration, that we may interchange the limits of ϑ and φ with those of ϑ' and φ', the result being the same if we let ϑ' and φ' vary between the limits ϑ_1 and ϑ_2, φ_1 and φ_2, and ϑ and φ over the whole sphere.

Next, let α and β be the components of the motion of a star (v) in and across the line of sight, respectively; a its proper angular velocity and d its distance; $\mathrm{M}(a)$, $\mathrm{M}(d)$ and $\mathrm{M}(ad)$ the

mean values of a, d and ad; then in the case of distribution over a whole sphere or hemisphere,

$$\beta = ad, \qquad \mathrm{M}(\beta) = \mathrm{M}(ad) = \frac{\pi}{2}\mathrm{M}(\alpha).$$

Now let $a_1, a_2, \ldots, d_1, d_2, \ldots$ refer to the particular stars, and let n be their number; we have then

$$\mathrm{M}(ad) = \frac{\Sigma(ad)}{n} = \frac{a_1 d_1}{n} + \frac{a_2 d_2}{n} + \frac{a_3 d_3}{n} + \ldots + \frac{a_n d_n}{n},$$

$$\mathrm{M}(a)\mathrm{M}(d) = \frac{\mathrm{M}(d)\Sigma(a)}{n} = \frac{a_1 \mathrm{M}(d)}{n} + \frac{a_2 \mathrm{M}(d)}{n} + \frac{a_3 \mathrm{M}(d)}{n} + \ldots + \frac{a_n \mathrm{M}(d)}{n}.$$

Subtracting the second of these equations from the first, we have

$$\mathrm{M}(ad) - \mathrm{M}(a)\mathrm{M}(d) = \tfrac{1}{n}\{a_1[d_1 - \mathrm{M}(d)] + a_2[d_2 - \mathrm{M}(d)] + \ldots + a_n[d_n - \mathrm{M}(d)]\}.$$

Now the sum of the coefficients of a_1, a_2, etc. is $\Sigma(d) - n\mathrm{M}(d) = 0$; so that some of the terms within the braces will be positive and some negative. And since positive and negative values for $a_1[d_1 - \mathrm{M}(d)]$, $a_2[d_2 - \mathrm{M}(d)]$, etc., are equally probable, the sum of these terms will be some small finite quantity ϵ, and the last equation becomes

$$\mathrm{M}(ad) - \mathrm{M}(a)\mathrm{M}(d) = \frac{\epsilon}{n}.$$

If n is practically infinite, as we have supposed it, the right-hand member of this equation vanishes; giving us, by the previous results,

$$\mathrm{M}(d) = \frac{\mathrm{M}(ad)}{\mathrm{M}(a)} = \frac{\pi}{2} \cdot \frac{\mathrm{M}(\alpha)}{\mathrm{M}(a)} = \frac{\pi}{2} \cdot \frac{\Sigma(\alpha)}{\Sigma(a)};$$

thus reducing the required mean distance d to a simple function of the mean angular velocity and the mean velocity in the line of sight.

Although we cannot employ an infinite number of stars in calculation, yet the error will be quite small if a very large number of stars be used, provided their motions really are at random, *i. e.* show no "drift" in any particular direction. But, as previously hinted, because of the comparatively small number of stars whose velocities in the line of sight and angu-

lar motions are accurately known, this result can be of little practical value at the present stage of astronomy. As an interesting example of the principle, however, it may be worth while to apply it, making the best use of the material at hand. As nearly all the stars, whose velocities in the line of sight have been measured, are in the northern hemisphere, I will find the mean distance ot stars in this hemisphere only. The annexed table includes the available data, gathered from the following sources: the right ascensions, north polar distances and magnitudes are taken from the "Catalogue of Almanac Stars" in Professor Pickering's *Annals of Harvard College Observatory*, 1890, the positions being reduced to 1900·0. The proper motions are computed from the Greenwich *Ten Year Catalogue* of 1887, and where possible, also, from Newcomb's list in *Astronomical Papers for the American Ephemeris and Nautical Almanac* (1882), the latter measurements being given the greater weight. The data of the last two columns are taken partly from Scheiner's new *Spectral-analyse* and partly from the record of observations at Greenwich and Potsdam given in the *Monthly Notices of the Royal Astronomical Society.* From this table we find, neglecting signs,

$$\Sigma(\alpha) = 18{\cdot}670, \text{ in seconds of arc per year.}$$
$$\Sigma(\alpha) = 1620{\cdot}7, \text{ in miles per second.}$$

Before dividing the latter value by the former, we must reduce them to the same units by constant factors. With this alteration, our equation may be expressed as

$$\mathrm{M}(d) = \frac{\pi}{2} \cdot \frac{c_1 \Sigma(\alpha)}{c_2 \Sigma(a)} = \mathrm{C} \frac{\Sigma(\alpha)}{\Sigma(a)},$$

in which, taking our unit of length as the mile,

$$c_1 = 86400 \times 365{\cdot}256, \qquad c_2 = \frac{\pi}{180 \times 3600}$$

$$\mathrm{C} = \frac{\pi c_1}{2 c_2} = 10{,}224{,}841{,}560{,}000\,;$$

giving us as a mean distance

$$\mathrm{M}(d) = 887{,}595{,}111{,}000{,}000 \text{ miles,}$$

equivalent to 9,596,000 astronomical units, or about 150·9 light-years.

Before going further, however, it is necessary to return to a consideration of our values for line-of-sight motions, on whose accuracy the result chiefly depends. A glance over the table will show that they fall at once into two classes: Vogel's

(including his assistant, Dr. Scheiner's) and those which are not Vogel's; the former class containing 48 and the latter 47 of the 95 stars used. The latter observations, besides being widely variant among the different observers, have been shown by Professor Vogel's measurements* to be nearly all *too large;* which influences the result correspondingly. Vogel's measurements have accordingly been invariably used, where possible, to the exclusion of others; being estimated with approximate accuracy to the tenth of a mile. Although compelled to halve our already small number of stars, yet it may be worth while to collect Dr. Vogel's observations (and the appropriate proper motions) in the same manner as above, not only for purpose of comparison, but with a probably much more accurate result. This gives us

$$\Sigma(a) = 10{\cdot}994, \quad \Sigma(\alpha) = 508{\cdot}7;$$

from which we obtain

$$M(d) = 473{,}110{,}506{,}000{,}000 \text{ miles}$$

equivalent to 5,115,000 astronomical units, or about 80·5 light-years, a little more than half the previous value.

But it is to be noticed that these results, even if entirely free from errors of observation, are only for the brightest stars (since these alone give sufficient light for present spectroscopic measurements), and hence for the nearest. But in any case they can be only provisional, for several reasons,—first, as previously stated, on account of the comparatively small number of stars. Again, these stars, though distributed with approximate uniformity, will be seen to be very scarce in places occupied by the Milky Way, *e. g.* between the hours of 5 and 9, and 22 and 24, in right ascension. Again, as regards their motions being at random, an examination of their directions (omitted for lack of space) will show that on one side of the hemisphere the motion is almost entirely to the south, while on the other side it tends toward the north; and a similar aggregation of signs will be noticed among the motions in right ascension.†‡

* Following are Professor Vogel's observations in connection with his "List of 51 Stars." *Monthly Notices R. A. Soc.*, June, 1892: "Greatest observed velocities, +30·2 mi. (a Tauri); −24·0 mi. (γ Leonis). Average velocity, 10·4 mi. No. of stars with velocity greater than 10·4 mi., positive 7, negative 11. Average probable error of the measurements for a single plate and one observer, ±1·6 mi."

† Similarly Professor Vogel notes of his observations, nearly all of which are in the northern hemisphere (*Monthly Notices*, vol. lii, p. 96), that "fifteen of the stars have a positive and thirty-two a negative motion."

‡ This is due, I suppose, in part, at least, to the motion of the sun in its "way," as the signs correspond pretty closely to what this motion would tend to make them. It will be seen that when the stars are taken over a whole sphere, or a hemisphere (as above), any *general rectilinear drift*, common in magnitude and

All these difficulties, however, may in time be eliminated. A sufficient number of stars to calculate from is, in fact, a matter only of time. These stars may then be selected with regard to uniform distribution, and any drifts seen in certain parts of the sky (if such are large enough to be worth consideration) be allowed for in the equations. Professor Vogel's new spectrographic method* promises accuracy amply sufficient, if, as he claims, the probable error of the measurements is less than one mile per second. We might even go so far, in our speculative fancy, as to classify the stars according to their spectra, and find the average distance of each class from our system; thus throwing some light on its real distribution in the universe, and on our position with respect to the various classes.†

Table of 95 Stars used in the Calculation.

The stars are arranged in order of right ascension. The total proper motion of a star across the line of sight is given by the formula $a = \sqrt{\nu^2+(15\rho)^2\sin^2 D}$, in which ν and ρ are the motions in N. P. D. and R. A. respectively, and D is the N. P. D. That is, a is considered the hypotenuse of a rectilinear right triangle of which ν and $15\rho \sin D$ (in seconds of arc) are the sides.

In the sixth column, the + and − signs denote recession and approach of the star, respectively. The letters G, H, S and V represent Greenwich Observatory, Huggins, Seabroke and Vogel respectively (two or more for the same star representing a mean of different observers); but V-S denotes Vogel's mean of his own and Scheiner's measurements given in his "List of 51 Stars" (*Monthly Notices*, June, 1892).

A few stars whose N. P. D. is slightly greater than 90° have been inserted, by which discrepancy however the accuracy of the result is not sensibly affected. The quantities in parenthesis were not given in the sources referred to.

direction to all the stars considered, does not affect the ratio $\frac{M(\beta)}{M(\alpha)}=\frac{\pi}{2}$; for if the stars had no other motion, this ratio would remain the same. The motion of the sun in its way may, indeed, be thus found by Doppler's principle.

* See *Monthly Notices R. A. Soc.*, December, 1891.

† It is curious to note that Mr. Monck has already discovered that "solar stars of any magnitude will, on the average, have a greater proper motion than the Sirian" (*Messenger*, Nov., 1891)—a statement strongly confirmed by Mr. J. E. Gore's list (*Astronomy and Astrophysics*, Jan. 1892), in which 26 of the 29 greatest proper motion stars whose spectra have been observed are shown to be of the solar class. This may, of course, be suggestive of their relative distance.

Name of Star.	R. A. Hours.	N. P. D. °	Mag.	Proper Annual Motion. a ″	Motion in Line of Sight a Miles per sec.	Observer.
α Androm.	0·05	61·5	2·1	·211	− 2·8	V-S
β Cassiop.	0·06	31·4	2·4	·550	− 3 2	V-S
γ Pegasi	0·13	75·4	2·8	·172	−19·	G & S
δ Androm.	0·57	59·7	3·5	·152	−40·	G
α Cassiop.	0·58	34·0	2·3	·064	+ 9·5	V-S
γ Cassiop.	0·84	29 8	2·3	·018	+ 2·2	V-S
β Androm.	1·07	54·9	2·2	·214	− 7·0	V-S
α Urs. Min.	1·37	1·2	2·2	·042	−16·1	V-S
δ Cassiop.	1·32	30·3	2·8	·294	−14·	G
α Triang.	1·79	60·9	3·5	·231	+56·	G
β Arietis	1·82	69·7	2·8	·138	−27·	G
α Piscium	1·95	87·7	(3·5)	·026	−29·	G
γ Androm.	1·96	48·1	2·2	·056	− 8·0	V-S
α Arietis	2·02	67·0	2·1	·235	− 9·2	V-S
α Ceti	2·95	86·3	2·6	·088	−16·	G
β Persei	3·03	49·4	2·3	·022	− 1·0	V-S
α Persei	3·29	40·5	1·9	·042	− 6·4	V-S
δ Persei	3·60	42·5	3·1	·051	+30·	G
η Tauri	3·69	66·2	3·1	·183	−23·	G
ζ Persei	3·80	58·4	3·0	·027	−24·	G
ϵ Tauri	4·38	71·0	3·6	·111	+20·	G
α Tauri	4·50	73·7	1·0	·198	+30·2	V-S
α Aurigæ	5·15	44·1	0·1	·438	+15·2	V-S
γ Orionis	5·33	83·7	1·7	(·090)	+ 5·7	V-S
β Tauri	5·38	61·5	1·8	·182	+ 5·0	V-S
δ Orionis	5·45	90·4	2·3	·012	+ 0·6	V-S
ϵ Orionis	5·52	91·3	1·8	·016	+16·5	V-S
ζ Orionis	5·59	92·0	1·9	(·090)	+ 9·3	V-S
α Orionis	5·83	82·6	0·9	·024	+10·7	V-S
β Aurigæ	5·87	45·1	2·0	·070	−17·5	V-S
γ Gemin	6·53	73·5	2·0	·049	−10·3	V-S
β Can. Min.	7·36	81·5	3·1	·069	−14·	G
α Gemin.	7·47	57·9	1·9	·193	−18·4	V-S
α Can. Min.	7·57	84·5	0·5	1·254	− 5·7	V-S
β Gemin.	7·65	61·7	1·2	·632	+ 0·7	V-S
ϵ Leonis	9·67	65·8	3·2	·062	− 4·	G
α Leonis	10·05	77·5	1·3	·259	− 5·7	V-S
γ Leonis	10·24	69·6	2·5	·320	−24·0	V-S
β Urs. Maj.	10·93	33·1	2·4	·082	−18·2	V-S
α Urs. Maj.	10·95	27·7	2·0	·145	− 7·2	V-S
δ Leonis	11·15	68·9	2·7	·194	− 8·9	V-S
ϑ Leonis	11·15	74·0	3·5	·106	+16·	G & S
β Leonis	11·73	74·9	2 2	·519	− 7·6	V-S
β Virginis	11·76	87·7	3·7	·778	−43·	G
γ Urs. Maj.	11·81	35·7	2·4	·099	−16·5	V-S
δ Urs. Maj.	12·17	32·4	2·7	·107	+11·	G & H
γ Virginis	12·61	90·9	2·9	·566	+ 6·	G
ϵ Urs Maj.	12·83	33·5	1·9	·097	−18·8	V-S
δ Virginis	12·84	86·1	3·5	·505	+63·	G
α Can. Ven.	12·86	51·1	3·2	·233	−29·	G
ϵ Virginis	12·95	78·5	3·1	·284	−11·	G
ζ Urs. Maj.	13·33	34·5	2·5	·123	−19·4	V-S
ζ Virginis	13·49	90·1	3·6	·303	−43·	S
η Urs. Maj.	13·73	40·2	1·9	·111	−16·3	V-S
η Boötis	13·83	71·1	2·8	·362	−24·	G & S
α Dracon.	14·03	25·1	3·7	·048	+35·	G
α Boötis	14·18	70·3	0·2	2·285	− 4·8	V-S

Name of Star.	R. A. Hours.	N. P. D. °	Mag.	Proper Annual Motion. *a*. ″	Motion in Line of Sight *a* Miles per sec.	Observer.
γ Boötis	14·47	51·2	3·2	·197	−38·	G
ε Boötis	14·68	62·5	2·6	·044	−10·1	V-S
β Urs. Min.	14·85	15·4	2·2	·028	+ 8·9	V-S
β Boötis	14·97	49·2	3·7	·062	−42·	G
α Cor. Bor.	15·51	62·9	2·3	·154	+19·9	V-S
α Serpent.	15·65	83·3	2·7	·133	+14·	V
β Serpent.	15 69	74·3	3·7	·060	−14·	G
ε Serpent.	15·76	85·2	3·7	·133	+35·	G
γ Hercul.	16·29	70·6	3·8	·084	−27·	G
η Dracon.	16 38	28·3	2·8	·059	+10·	G
β Hercul.	16·43	68·3	2·8	·107	−22·0	V-S
ζ Hercul.	16·62	58·2	2·9	·612	−25·	G
ζ Dracon.	17·14	24·2	3·4	·028	−30·	G
α Hercul.	17·17	75·5	3·1	·034	−26·	G
β Dracon.	17·47	37·6	3·0	·014	+17·	G
α Ophiu.	17·50	77·4	2·2	·253	+11·9	V-S
ξ Dracon.	17·86	33·1	(3·5)	·144	+ 8·	G
γ Dracon.	17·90	38·5	2.5	·032	+12·	V
α Lyræ	18·56	51·3	0·2	·325	− 9·5	V-S
γ Lyræ	18·92	57·4	3·3	·029	−34	G & S
ζ Aquilæ	19·01	76·3	3·1	·102	−30·	G & S
δ Aquilæ	19 36	87·1	3·5	·251	+ 2·	G
β Cygni	19·44	62·2	3·1	·026	−13·	G
γ Aquilæ	19·69	79·6	2·8	·010	−13·	G & S
δ Cygni	19·70	45·1	2·9	·060	−20·	G & S
α Aquilæ	19·76	81·4	0·9	·648	−22·9	V-S
γ Cygni	20·31	50·1	2·3	·021	− 4·0	V-S
α Delph.	20·58	74·4	3·9	·045	− 8·	G
α Cygni	20·63	45·1	1·4	·008	− 5·0	V-S
ε Cygni	20·70	56·4	2·6	·485	− 8·	G & S
ζ Cygni	21·14	60·2	3·3	·070	+ 6·	G
α Cephei	21.27	27·8	2·6	·157	−41·	G
β Cephei	21·46	19·9	3·4	·012	+53·	G
ε Pegasi	21·65	80·6	2·4	·023	+ 5·0	V-S
ζ Pegasi	22·61	79·7	3·5	·073	− 6·	G
η Pegasi	22 64	60·3	3·0	·033	− 9·	G & S
β Pegasi	22·98	62·5	2·5	·219	+ 4·1	V
α Pegasi	22·99	75·5	2·5	·063	+ 0·8	V-S

Art. XXXII.—*On the Double Halides of Tellurium with Potassium, Rubidium and Cæsium;* by H. L. Wheeler.

The existence of double halides of tellurium with potassium, sodium and ammonium was first indicated by Berzelius.* He described the methods by which he obtained them, but gave no analyses of the compounds. Later, Rammelsberg† investigated the double chlorides of tellurium with potassium and ammonium, with the object of determining their composition. He arrived at the formulæ $8KCl \cdot 3TeCl_4$ and $8NH_4Cl$.

* Pogg. Ann., xxxii, 577.

† Berlin Monats. Ber., 1875, 379.

$3TeCl_4$. It will be shown beyond that the formula of the potassium compound at least must have been obtained from analyses of impure products. Von Hauer* analyzed the double bromide of tellurium and potassium, and concluded that the salt had the composition represented by the formula $2KBr.TeBr_4.3H_2O$. I have reinvestigated this salt and found it to contain two molecules of water and not three. Probably Von Hauer analyzed the salt without previously having dried it sufficiently or without having taken precautions to remove included water which the crystals always contain. He dehydrated this salt and used it in his work on the atomic weight of tellurium.

More recently Wills† determined the atomic weight of tellurium by means of the same salt. He does not give any analyses of the hydrous compound, but states that the salt contains water and gives directions for dehydrating it. Rammelsberg in his "Handbuch der krystallographisch-physikalischen Chemie" (p. 289) quotes the formula of the dehydrated compound from Wills' work and assigns to this Baker's‡ measurements, which do not belong to it, but to the hydrated compound with the three supposed molecules of water of crystallization. The present investigation has shown that the anhydrous salt is isometric, the hydrous one being orthorhombic.

Ramsay§ says that "By mixing aqueous solutions of the constituent halides, tellurium halides combine thus: $TeCl_4$ $2KCl$, $TeBr_4 2KBr$, $TeI_4 2KI$. These compounds form reddish crystals. Few attempts have been made to prepare double halides." Although a thorough search of the literature on this subject has been made, in connection with the present work, no analyses of the double chloride or iodide could be found. Berzelius's work as regards their preparation and Rammelsberg's attempt to determine the formula of the chloride comprise all the work that has been done on these two salts. It must be concluded that the formulæ given by Ramsay were deduced by analogy with the double bromide, especially since his statements in regard to color, method of preparation and composition only apply, in all respects, to the double bromide.

It will be seen from the above summary that very little satisfactory work has been done on this class of compounds, and, therefore, the present investigation has been undertaken with the view of making a thorough study of the double

* Journ. prakt Chem., lxxiii, 98.
† Jour. Chem. Soc., xxxv, 711.
‡ Jour. Chem. Soc, xxxv, 711.
§ System of Inorganic Chemistry, edition of 1891, p. 168.

halides of tellurium with potassium, rubidium and cæsium. As a result the following compounds have been prepared:

$2KCl \cdot TeCl_4$	$2RbCl \cdot TeCl_4$	$2CsCl \cdot TeCl_4$
$2KBr \cdot TeBr_4$	$2RbBr \cdot TeBr_4$	$2CsBr \cdot TeBr_4$
$2KBr \cdot TeBr_4 \cdot 2H_2O$	$2RbI \cdot TeI_4$	$2CsI \cdot TeI_4$
$2KI \cdot 2TeI_4 \cdot 2H_2O$		

It is to be noticed that all of these compounds conform to the usual type of double halides of tetravalent metals in containing the alkali metal and tellurium in the ratio of two atoms of the former to one of the latter, and no indications of the formation of salts of a different type were observed. The anhydrous double halides of tellurium crystallize in the isometric system, with an octahedral habit, and it is an interesting fact that this form seems to be characteristic for anhydrous double halides of this type. The cæsium and rubidium salts are new compounds, as well as the crystallized, anhydrous, double potassium bromide. New formulae have been assigned to the hydrous potassium double bromide and to the double iodide of potassium. A considerable difference is shown in the affinity of the double halides of tellurium and potassium for water of crystallization. The double chloride is anhydrous and no hydrous form of it was observed, the double bromide was prepared in both the hydrous and the anhydrous forms, while the iodide was obtained only with water of crystallization. This water was more firmly held than in the case of the hydrous bromide, as was shown by the fact that it formed from hot solutions and did not as readily effloresce.

The methods used in the preparation of pure material for this work, and which deserve to be mentioned on account of giving satisfactory results, are given below. The tellurium was obtained by purifying the commercial product by precipitation with sulphurous acid, according to the method of Divers and Shimosé.* The halides of tellurium were prepared from this material in the usual way.

Cæsium chloride was obtained in a pure state by the method of Godeffroy.† The bromides and iodides were obtained in the usual manner from the carbonate, the latter having been prepared from the pure chloride by converting into nitrate, then into oxalate and igniting the latter, as suggested by J. L. Smith,‡ for the conversion of potassium chloride into carbonate. The rubidium was purified by Allen's§ acid tartrate method. In the case of the potassium salts, Kahlbaum's pure material was used.

* Jour. Chem. Soc., xlvii, 439.
‡ This Journal, II, xvi, 373.
† Ber d. chem. Ges., vii, 375.
§ Ibid., II, xxxiv, 367.

The methods by which the double halides were obtained will be given with the description of the salts.

Method of Analysis.

The anhydrous salts were removed from the mother liquor, and, after pressing on filter paper, were dried in the air. The hydrous compounds were rapidly crushed on smooth filter paper, and, as soon as it was certain that no included water was retained by the fragments, they were placed in weighing tubes. Portions of about one-half a gram were taken for analysis. In order to determine the halogens, silver sulphate was added to the solution of the weighed sample in water containing a little sulphuric acid. The silver halide was washed, ignited and weighed in the usual manner. After the removal of the excess of silver by means of hydrochloric acid, tellurium was removed with hydrogen sulphide. This separation of tellurium, best in warm solution, has been found to be complete in a few minutes and in a condition that admits of filtration without inconvenience. The sulphide of tellurium, filtered on asbestus in a Gooch crucible, was washed with water containing a little hydrogen sulphide, then treated with a solution of bromine in dilute hydrochloric acid, which readily dissolves the moist sulphide. An excess of nitric acid was then added to this solution and the whole evaporated on the water bath, the resulting tellurous acid, being transferred to platinum, was ignited and weighed as TeO_2. The alkali metals were determined by evaporating the filtrate from the tellurium sulphide to dryness, with an excess of sulphuric acid. The residues were then converted into normal sulphate by ignition in a stream of ammonia, as suggested by Krüss for potassium sulphate. In the case of the hydrous salts, water was determined by heating them in an air bath to constant weight; the residues were analyzed and found to correspond in composition to the anhydrous salts. The atomic weights used in the calculation of the results were the following:

Te, 125; K, 39·1; Rb, 85·5; Cs, 133; Cl, 35·5; Br, 80; I, 127.

Solubility.

The salts are all decomposed by water. The double bromides, however, show an interesting difference in their deportment with this reagent. Potassium tellurium bromide dissolves in a small amount of water, but, if an excess of water is added, tellurous acid separates, as has been observed by Wills.* Rubidium tellurium bromide also dissolves in a

* loc. cit.

little hot water completely, the difference being shown on cooling, when a considerable portion of the tellurium separates as tellurous acid. While in the case of the cæsium salt both hot and cold water, in large and small amounts, fail to dissolve the salt, the result being immediate decomposition. Only a small part of the tellurium in this case goes into solution. Most of these double salts can be conveniently recrystallized from dilute solutions of the corresponding acid. The exceptions are potassium-tellurium chloride, which is decomposed by this treatment, and cæsium-tellurium iodide, which is practically insoluble in hydriodic acid. The fact, first noticed by Godeffroy,* that double halides, containing the metals potassium, rubidium and cæsium, generally decrease in solubility from potassium to cæsium, which has frequently been noticed in this laboratory, is again well illustrated by these compounds. For the determination of the solubility of these salts in acids, they were finely powdered, and saturated solutions were then prepared by digesting a mixture of the acid and an excess of the salt for about a week, at ordinary temperature. This was done in a closed flask. Weighed portions of these solutions were evaporated to dryness and the residues dried at 100° and weighed. These solubilities were all taken at 22°, and the results are the average of two or more closely agreeing determinations.

	100 parts HCl Sp. gr. 1·2 dissolve	100 parts HCl Sp. gr. 1·05 dissolve
$2RbCl . TeCl_4$	0·34 parts.	13·09 parts.
$2CsCl . TeCl_4$	0·05 "	0·78 "

	100 parts HBr Sp. gr. 1·49 dissolve	100 parts HBr Sp. gr. 1·08 dissolve
$2KBr . TeBr_4$	6·57 parts.	62·90 parts.
$2RbBr . TeBr_4$	0·25 "	3·88 "
$2CsBr . TeBr_4$	0·02 "	0·13 "

The double tellurium chlorides, described in this article, are more soluble than the bromides, and the bromides more soluble than the iodides. The solubility of these compounds in strong alcohol shows the same gradation as their solubility in acids, the cæsium salts being practically insoluble in this menstruum, while the rubidium salts dissolve to a trifling but clearly perceptible extent, and the potassium salts dissolve considerably or are decomposed with separation of the potassium halide, or both solution and decomposition take place, according to the salt experimented with.

* Ber. d. Chem. Ges., viii, 9.

The Chlorides.

The crystals of the three chlorides have a pale yellow color, resembling that of the well known ammonium phospho-molybdate precipitate, the shade becoming somewhat lighter from the cæsium to the potassium salts.

Cæsium tellurichloride, $2CsCl.TeCl_4$.—In the preparation of this compound, and also in the preparation of the rubidium and potassium double chlorides, the tellurium tetrachloride is most conveniently made by converting tellurium into tellurous oxide by means of aqua regia, evaporating to dryness to expel nitric acid and then dissolving the residue in hot hydrochloric acid. An aqueous solution of cæsium chloride, added to this, produces a precipitate, even in quite dilute solutions. There must be an excess of hydrochloric acid present to prevent the separation of tellurous acid. On boiling and adding more water, if necessary, this precipitate dissolves. The solution, left to cool, deposits small brilliantly lustrous octahedrons. It is a general fact with these double halides, that an excess of one or the other of the constituents does not affect their composition. This is shown in this particular case by the fact that it can be recrystallized from strong solutions of tellurium or of cæsium chlorides.

		Analysis gave:		Calculated.
Cs	43·44	43·90	44·63	44·04
Te	20·65	----	21·41	20·69
Cl	35·93	35·14	----	35·27

This compound is perfectly stable in the air. It does not melt below the boiling point of sulphuric acid. It can be precipitated from its solution in dilute hydrochloric acid by the addition of concentrated hydrochloric acid. A portion of the salt, finely pulverized, was treated with water at ordinary temperature. This produced a voluminous white precipitate, which was washed with cold water and dried in the air.

	Analysis gave:	Calculated for H_2TeO_3.
Te	71·43	71·43
H_2O	7·52	10·29
O	17·76	18·28
Cl	2·49	
Cs	0·80	

The oxygen which was not given off in the form of water on heating the substance was calculated by difference. From the above analysis the conclusion may be drawn, that the precipitate produced by the action of water on this salt is essentially tellurous acid, a small amount of oxychloride of tellurium

being present. Hot water dissolves some of this tellurous acid, and, on cooling slowly, the anhydride separates in the characteristic form of colorless octahedrons.

Rubidium tellurichloride, $2RbCl.TeCl_4$.—The preparation of this salt was in every way analogous to that of the cæsium tellurium chloride. However, since this salt is far more soluble than the corresponding cæsium compound, no precipitate was obtained in dilute solutions. The mixture of the hydrochloric acid solution of the constituents was concentrated by evaporation, and, when cooled, crystals separated. These were in the form of octahedrons, somewhat larger than the cæsium salt.

	Analysis gave:		Calculated for $2RbCl.TeCl_4$.
Rb	33·50	33·83	33·59
Te	24·34	----	24·56
Cl	----	----	41·85

This salt remains permanent in the air. From the dilute hydrochloric acid solution, concentrated hydrochloric precipitates it unaltered. Water decomposes it, evidently in the same way as the cæsium salt.

Potassium tellurichloride, $2KCl.TeCl_4$.—To prepare this salt in a pure state an excess of tellurium chloride is necessary. The analyzed material was obtained by spontaneous evaporation of the constituents in a solution of dilute hydrochloric acid, twice as much tellurium chloride being present as required by the formula. Under these conditions it was found to separate in the form of light yellow octahedrons, which, under the microscope, were shown to be free from potassium chloride.

	Analysis gave:	Ratio.	Calculated for $2KCl.TeCl_4$.
K	17·37	·44	18·79
Te	30·29	·24	30·03
Cl	49·47	1·39	51·18
	97·13		

The salt, therefore, has the formula $2KCl.TeCl_4$. The crystals deliquesce somewhat in moist air and the analyzed material retained a small amount of water, as is shown by the deficiency in the above analysis. It is not probable that the salt contains water of crystallization, for the crystalline form and optical properties show that it is isomorphous with the anhydrous salts. This salt is the most unstable as well as the most soluble of the anhydrous double halides described in this article. It is readily dissolved by dilute hydrochloric acid.

Strong hydrochloric acid separates potassium chloride. It therefore cannot be precipitated from its solutions by the addition of strong hydrochloric acid, as in the case of the other chlorides. Alcohol also separates potassium chloride. Water apparently effects the same decomposition as in the case of the cæsium and rubidium chlorides. The tendency of potassium chloride to separate along with the salt explains why Rammelsberg's analysis came high in regard to the potassium chloride. His results corresponded to a mixture of two molecules of KCl and three molecules of $2KCl . TeCl_4$. Experiments with the calculated quantity of the constituents invariably resulted in the separation of potassium chloride or potassium chloride mixed with the yellow $2KCl . TeCl_4$. Experiments with the method given by Ramsay* for the preparation of this salt, by mixing aqueous solutions of the constituents, resulted in the decomposition of the tellurium chloride, and the resulting white precipitate failed to dissolve until considerable hydrochloric acid was added. Attempts to prepare the compound by concentrating the mixture of the constituents by the aid of heat invariably resulted in failure. In certain cases, on cooling such solutions, a mass of colorless slender prisms was obtained, which will be described in a future article.

The Double Bromides.

The crystals of the anhydrous bromides have a brilliant red color resembling that of the mineral crocoite. The powders of the salts have a color that is similar to that of a mixture of equal parts potassium bichromate and red lead. The powder of the hydrous bromide has the color of mercuric oxide, but, by loss of water, this soon changes to that of the anhydrous salt.

Cæsium telluribromide, $2CsBr . TeBr_4$.—This double halide can easily be prepared by mixing finely divided tellurium with cæsium bromide in dilute hydrobromic acid, then adding bromine in excess. The presence of free acid is necessary to prevent the separation of tellurous acid. When the tellurium has disappeared, the solution is concentrated by the aid of heat, and, on cooling, bright red crystals of the pure salt are deposited. These are generally somewhat larger than the crystals of the double chloride.

	Analysis gave:			Calculated.
Cs	30·90	30·87	30·91	30·54
Te	14·29	13·60	14·03	14·35
Br	55·01	....	55·32	55·11

* loc. cit.

This salt remains unaltered in the air. It can be separated from its solution in dilute hydrobromic acid by the addition of concentrated acid. It does not melt below the boiling point of sulphuric acid. Attempts to prepare a hydrous salt according to the methods used for the preparation of $TeBr_4 . 2KBr . 2H_2O$ were without success.

Rubidium telluribromide, $2RbBr . TeBr_4$.—The directions given for the preparation of the corresponding cæsium compound apply also in the preparation of this salt. If the solutions are strong, the compound separates as a bright red precipitate, but if dilute, on concentrating by means of heat or spontaneous evaporation, it crystallizes in brilliant red octahedra.

	Analysis gave:	Calculated.
Rb	22·02	22·04
Te	----	16·11
Br	62·07	61·85

This salt is stable in the air. Like the corresponding cæsium salt, this separates from its solutions by the addition of concentrated hydrobromic acid. When it is dissolved in a little water and the solution is cooled slowly, colorless octahedrons of TeO_2 separate. The latter product was found to be impure, containing a small amount of bromine. On heating, the salt decrepitates slightly and melts at a high temperature. Efforts to prepare a hydrous salt according to the methods used for the preparation of $2KBr . TeBr_4 . 2H_2O$ were without success.

Potassium telluribromides, $2KBr . TeBr_4$ *and* $2KBr . TeBr_4 . 2H_2O$.*—For the preparation of these salts, a mixture of the constituents was made as described in the case of the cæsium double bromide. The solution invariably deposited crystals of the anhydrous salt when it had been concentrated by heat, but, by spontaneous evaporation of the filtrate, the hydrous salt was obtained. On recrystallizing either of these salts from water or from dilute hydrobromic acid, the anhydrous salt is obtained when the solution has been saturated by boiling and then allowed to cool, but if the solution is left to deposit crystals at ordinary temperature the hydrous modification is obtained. The crystals of these different compounds closely resemble each other in color and appearance. The anhydrous variety crystallizes in octahedrons modified by the cube. The orthorhombic crystals of the hydrous salt look like distorted crystals of the other. This being the case, and since

* Described by Von Hauer as containing three molecules of water of crystallization.

the crystals of the hydrous compound can be obtained much larger than those of the anhydrous salt, both Von Hauer and Wills selected these for their work, while the more easily obtained anhydrous salt was overlooked. The hydrous salt is readily distinguished from the anhydrous one by its deportment on exposure to a dry atmosphere. The latter is stable, but under these conditions the hydrous compound rapidly effloresces, losing its luster, the faces of the crystals becoming superficially covered with a light reddish yellow and opaque layer of the anhydrous salt. Crystals which had been exposed to dry air for several days and were completely covered with this layer were found, on crushing, to remain unaltered in the interior and to have still retained included water in addition to their water of crystallization. This was shown by the fact that the crushed crystals gave a stain of the mother liquor to filter paper. This property of the hydrous crystals explains why Von Hauer assigned three molecules of water to this salt instead of two. The material for analysis of the hydrous salt was selected from crystals varying in size from 7 to 13^{mm} in diameter. These were very rapidly crushed on smooth filter paper, to remove included water, and immediately corked up in the weighing tube and analyzed. A close examination of the fragments, before and after weighing, gave no evidence of loss of water from the substance by efflorescence. The analyses were from three different crops.

	Analysis gave:			Calculated for $2KBrTeBr_4 . 2H_2O$.	Calculated for $2KBrTeBr_4 . 3H_2O$.
K	10·90	11·07	10·73	10·87	10·61
Te ...	17·59	17·29	17·46	17·38	16·96
Br ...	66·35	66·36	66·34	66·74	65·11
HO ..	5·33	5·53	5·73	5·01	7·32

These results make it evident that the salt contains two molecules of water, and not three as has generally been supposed. The water in this salt was determined by heating it in an air bath to constant weight. The temperature was maintained between 150°–160°, and finally, to be sure that all the water had been driven off, the residues were analyzed in two cases.

	Analysis gave:		Calculated for $2KBr . TeBr_4$.
K	11·71	11·52	11·44
Te	18·29	18·58	18·30
Br	70·25	70·09	70·26

Analyses of products obtained by cooling hot saturated solutions gave the following results :

				Calculated for $2KBrTeBr_4$.
K	11·67	11·70	----	11·44
Te	18·06	----	----	18·30
Br	70·24	70·20	69·40	70·26

The Double Iodides.

These salts are all black. The powder of the cæsium salt is pure black, that of the rubidium and potassium salts is grayish black.

Cæsium telluriiodide, $2CsI . TeI_4$.—In order to prepare this salt, and also in the case of the rubidium and potassium compounds, tellurium tetraiodide was made by treating tellurous oxide with hydriodic acid. The iodide of tellurium is sparingly soluble in hydriodic acid, but, on mixing this solution with a solution of cæsium iodide, an amorphous black precipitate was obtained, even in very dilute solutions.

	Analysis gave:	Calculated for $2CsI . TeI_4$.
Cs	23·37	23·07
Te	10·51	10·84
I	65·17	66·09

This compound resisted all attempts to prepare it in a crystalline form. It is insoluble in cæsium iodide and in hydriodic acid, hence warming in the mother liquor failed to dissolve the salt. It is decomposed slowly by cold water, rapidly by hot, and apparently tellurous acid or anhydride separates. This generally is impure, being mixed with a dark colored residue containing iodine. On exposure the salt slowly loses iodine. In the open capillary it does not melt below the boiling point of sulphuric acid.

Rubidium telluriiodide $2RbI . TeI_4$.—This compound was prepared by mixing the constituents in the same manner as in the preparation of the corresponding cæsium salt. If the solutions are only moderately concentrated, a black amorphous precipitate is produced. Unlike the corresponding cæsium salt, it dissolves, to a slight extent, on warming in the mother liquor, and on cooling, black microscopic octahedrons are produced.

	Analysis gave:	Calculated for $2RbI . TeI_4$.
Rb	16·83	16·17
Te	----	11·81
I	72·07	72·02

This iodide is stable on exposure. Water effects the same decomposition as in the case of the cæsium salt. A small portion of this salt dissolves in strong alcohol, giving the color of a weak iodine solution.

Potassium telluriiodide, $2KI . TeI_4 . 2H_2O$. — This compound can most conveniently be prepared by boiling tellurium iodide in a strong solution of potassium iodide in dilute hydriodic acid. The solution, filtered while hot from any undissolved tellurium iodide, deposits long black prisms on cooling. These crystals attain considerable size, about 30^{mm} in length, when a large excess of potassium iodide is used. The mother liquor, on evaporation in a desiccator, deposits more of the salt, but the crystals have a different habit.

	Analysis gave:			Calculated for $2KI . TeI_4 . 2H_2O$.
K	8·41	8·70	8·39	7·81
Te	12·25	12·95	12·30	12·48
I	75·97	----	76·68	76·11
H_2O	3.57	----	----	3·60

For the determination of water in this compound the crystals were rapidly pressed on paper and immediately analyzed. It was found that the salt could be dehydrated at a temperature between 110°–115°, the resulting anhydrous salt being stable at that temperature. This was shown by an iodine determination in the residue. Analysis gave 78·78 per cent. of iodine, calculated for $2KI . TeI_4$ 78·94.

This salt is far more stable in the air than the corresponding bromide, but the crystals lose their luster in dry air, becoming dull black on account of a superficial efflorescence.

Crystallography.

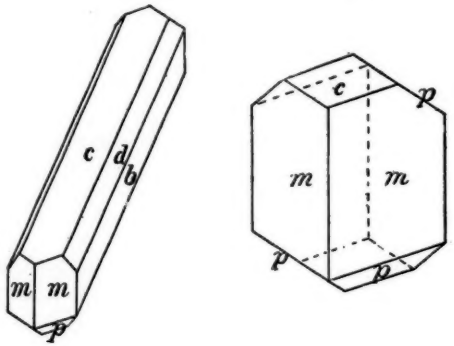
The crystallization of the anhydrous alkali-tellurium halides is isometric. The chlorides were obtained in octahedrons with little or no modification, the bromides in combination of octahedron and cube. The chlorides and bromides were measured and also proved to be isotropic by examination in polarized light. Of the anhydrous iodides, the rubidium salt was the only one obtained in crystals, and these were too small to measure, but appeared under the microscope as combination of octahedron and cube. They were so opaque that they could not be tested in polarized light.

The two hydrous salts, $2KBr . TeBr_4 . 2H_2O$ and $2KI . TeI_4 . 2H_2O$ although analogous to each other in their composition, differ in crystallization. The bromide is orthorhombic as has been shown by Baker* also by Grailich and Lang in Rammelsberg's Handbuch.† That the hydrous potassium tellurium bromide obtained in the present work is identical with that described by the above authors is shown by measurements of the crystals. The crystallization of the salt $2KI . TeI_4 . 2H_2O$ is

* Loc. cit. † Loc. cit.

monoclinic. Two different habits were observed; long prisms, developed in the direction of the clino axis, were obtained from hot solutions (fig. 1). The mother liquor from these, on standing, gave shorter prisms in which the domes and clino-pinacoids were wanting (fig. 2).

1. 2.



The forms observed were:

m 110	*c* 001	*d* 031
p 111	*b* 010	

The axial ratio is as follows:

$$\dot{a} : \bar{b} : \dot{c} \cdot 7047 ; 1 ; \cdot 5688 \quad B = 100 \wedge 001 = 59° 7' 16''$$

The crystals gave fair reflections of the signal on the goniometer. Measurements chosen as fundamental are indicated by an asterisk.

		Calculated.	Measured.
$m \wedge m''$	$110 \wedge 1\bar{1}0$	62° 20′	62° 26′
$m \wedge b$	$110 \wedge 010$	58° 50′	58° 50′ *
$b \wedge c$	$010 \wedge 001$	90°	90°
$m \wedge c$	$110 \wedge 001$	63° 57′	63° 57′ *
$m \wedge p$	$110 \wedge 11\bar{1}$	60° 42′	60° 42′ *
$c \wedge p$	$001 \wedge \bar{1}11$	55° 21′	55° 22′
$b \wedge d$	$010 \wedge 031$	34° 20′	34° 25′
$b \wedge p$	$010 \wedge 11\bar{1}$	61° 42′ 49″	61° 42′ 30″
$m \wedge m'$	$110 \wedge \bar{1}10$	117° 40′	117° 33′
$c \wedge m'$	$001 \wedge \bar{1}10$	116° 3′	116° 11′

The crystals were too opaque for any optical examination.

In conclusion the author wishes to express his indebtedness, to Prof. H. L. Wells for valuable advice and for the interest that he has taken in this work, and to Prof. S. L. Penfield under whose direction the crystallography of these salts was investigated.

Sheffield Scientific School, January, 1893.

ART. XXXIII.—*Tungstous Oxide—a new Oxide of Tungsten —associated with Columbous Oxide;** by WM. P. HEADDEN.

IN an article on some tin and iron compounds, an abstract of which appeared in this Journal,† reference was made to certain products as iron bottoms whose formation was then discussed at sufficient length. This paper is practically a study of the residues obtained from those bottoms.

The residues as obtained after having been freed from carbon and the portion which was so fine that it remained in suspension for a longer time, consisted of two parts, a heavier and a lighter. The specifically lighter one was quite readily attacked by hydric nitrate and the whole of the residues from the first two bottoms were treated with this salt in order to obtain the heavier portion as pure as possible.

The final residue from the first bottom was a brownish gray, very fine, crystalline, and wholly non-magnetic powder which under a magnification of 140 diameters, appeared to consist of prisms. It was examined after being ignited and found to contain columbic acid with a small quantity of tungstic acid and a very little iron and tin but no tantalic acid.

The residue from the second bottom was treated in a like way. The solution obtained by treating it with warm dilute hydric nitrate indicated the presence of compounds of tin and iron rich in the latter element. The tin went into solution and a small quantity of tungstic acid was formed; but it is uncertain whether it was derived from the soluble compounds or from the portion which remained as insoluble. I think that it was derived from the latter. The gray, crystalline residue, insoluble in warm dilute hydric nitrate was treated successively with cold concentrated hydric nitrate, aqua regia, water, and alcohol, and gave when subsequently treated with cold concentrated hydric chloride sp. gr. 1·2 a deep blue but clear solution, whose color was discharged by dilution with water and also upon being heated. The greater portion of this residue was strongly magnetic, the rest of it, however, was not attracted by the magnet. I could observe no difference in the form of the grains and crystals in the two portions. These were divided, by carefully washing them, into a finer crystalline and a coarser, well crystallized portion. The crystals are triangular prisms whose height is often several times the alti-

* Abstract of an article read before the Colorado Scientific Society, January meeting, 1893.

† Vol. xliv, p. 464.

tude of their triangular bases but not always so, as the prisms are sometimes very short. The triangular base is apparently equilateral and I interpret the form as a hemiprism belonging to the hexagonal system; the color is gray to tin-white and the luster is brilliant metallic. These crystals are sometimes grouped in clusters and then the larger ones are often invested with an abundance of smaller ones. Cases of penetration are frequent but no surfaces other than those indicated have been observed. Some of the crystals are striated, which is probably due to interference.

The magnetic portion of this second bottom, as used for analysis, consisted for the most part of crystalline particles. It oxidized slowly and imperfectly when fused with potassic hydric sulphate, but when heated to dull redness in an open crucible it ignited and burned to a voluminous powder, yellow while hot but nearly white when cold. Complete oxidation is effected with some difficulty. The results of the analysis No. I were:

		At. eq.			
Cb	37·72	40·13	10	14	1
W	29·04	15·80	4		
Fe	19·62	35·10	9		
Sn	5·04	4·27	1		
O	8·78	54·90	14	14	1
	100·20				

This suggests a mixture of $10CbO+4WO+Fe_9Sn$. Such a mixture would require 24·42 per cent of its weight of oxygen to completely oxidize it; the amount absorbed upon ignition was 24·88 per cent of its weight.*

The non-magnetic portion, analysis No. II, gave

*In separating tungstic and stannic oxides from columbic acid by digesting with ammonic sulphide and adding hydric chloride or sulphate to the alkaline solution, I have frequently obtained a yellow filtrate in which a further addition of hydric sulphate produced no precipitate. This reaction is due to the presence of potassic oxy-sulpho-tungstate $K_2WO_2S_2$ which is formed by the action of the ammonic sulphid on potassic tungstate formed during the fusion. The extent to which this salt may be formed is shown by the fact that in one instance I obtained rather more than one-third of all the tungstic acid present in this yellow filtrate from the mixed sulphide precipitate.

This salt is given in Gmelin-Kraut's Handbuch der Chemie, vol. ii, Part II, page 126, as being sometimes met with in the preparation of tungstic sulphide by fusing together potassic tungstate and sulphur—Berzelius; the same statement is given in Watt's Dictionary of Chemistry, vol. v, p. 914. But the reaction is not recorded anywhere, so far as I can find, as produced in the manner here given.

		At. eq.			
Cb	48·56	51·6	10·3	14·39	1·14
W	37·64	20·46	4·09		
Fe	3·22	5·75	1·15		
Sn	0·72	0·61	0·12		
O	10·08	63·00	12·60	12·60	1
	100·22				

The gain upon ignition amounted to 22·00 per cent of its weight. The formula suggested is the same as in the preceding case.

The third bottom showed, after a portion of it had been dissolved in hydric chloride, the triangular crystals disseminated throughout the mass and particularly abundant at the bottom. The residue in this case was not treated with warm hydric nitrate but was divided into three parts numbered 1, 2 and 3, beginning with the lightest.

PART 1. An analysis showed that this portion was a mixture of oxides and the ratio given for the metals to the oxygen was 1 : 1. When digested with cold hydric chloride, sp. gr. 1·2, it gave a clear blue solution whose color was discharged upon addition of water. The action of aqua regia upon it presented two phases, the first was very violent, while the second was quite slow; this was due to the fact that this reagent first dissolved the iron-tin compounds present, and then the tungsten or its compounds, which is evident from the following: some of this material was digested with two successive portions of aqua regia, each portion was evaporated to dryness after digestion at a gentle heat for about an hour; the first treatment gave $185{\cdot}7^{mgm}$ Fe_2O_3 and $81{\cdot}0^{mgm}$ WO_3, the second treatment gave $6{\cdot}7^{mgm}$ Fe_2O_3 and $51{\cdot}0^{mgm}$ WO_3. The residue from the first treatment consisted of triangular prisms, with a few crystalline grains, that from the second of remnants of such crystals, and after ignition consisted of tungstic acid with a small amount of columbic acid.*

PART 2. This consisted of crystalline grains and crystals. The latter were triangular prisms with an occasional six-sided plate; these plates which were relatively long and wide, were always pitted and had a much darker color than the prismatic crystals. The analysis of this showed 66·66 per cent of it to be difficultly soluble in aqua regia and emphasized the fact that the iron and tin do not belong to the triangular prisms which make up the larger part of the insoluble portion.

* In treating this portion with aqua regia containing a large excess of HCl, I obtained a clear yellow solution which gave upon addition of water a precipitate of tungstic acid; reference will be made to this reaction again.

The remainder of part 2 was persistently boiled with slightly diluted hydric nitrate, which attacks the iron and tin compounds much more readily than it attacks the crystals. The residue after being purified amounted to 42 per cent of the original quantity taken.

Neither the mixture itself nor the purified residue impart any color to a boiling concentrated solution of potassic hydrate, nor is there any evolution of ammonia or other reaction, but if the crystals are first digested with cold aqua regia and then potassic hydrate be added, the solution becomes brown upon standing, probably due to the formation of WO_3. The purified residue consisted very largely of the triangular prisms; some of the crystalline aggregations remained and the six-sided plates were still recognizable. When heated in the air it did not ignite but was slowly converted into a yellow powder. This residue was analyzed with the following results. Analysis III.

		At. eq.		
Cb	6·56	6·98	4·9	1·21
W	76·12	41·37	29·1	
Fe	9·06	16·18	11·4	
Sn	1·68	1·42	1·0	
O	6·34	39·63	28·0	1
	99·76			

The gain upon ignition equalled 20·66 per cent. If we calculate the columbium, tungsten and oxygen to one hundred we obtain Cb 7·37, W 85·57, O 7·12 = 100·00.

Portion No. 3, that is, the coarsest portion of the residue, was passed through a 148 mesh bolting cloth and the small portion which remained on the cloth was reserved for subsequent study. The portion used for analysis consisted of triangular prisms, which constituted as much as and possibly more than 85 per cent of the whole mass; the rest was made up of crystalline aggregations with a few of the six-sided plates noticed in the last sample. When ignited in the air it oxidized without incandescence to a yellow powder; the gain equalled 19·10 per cent; the analysis No. IV gave:

		At. eq.			
Cb	1·46	1·55	1·34	42·28	1·22
W	86·64	47·09	40·94		
Fe	4·32	7·71	6·70		
Sn	1·36	1·15	1·00		
O	6·32	39·50	34·35	34·35	1·00
	100·10				

This and also the preceding analysis indicates an excess of tungsten over that required by the oxygen for the formation of tungstous oxide. But if there remained any metallic tungsten in the regulus we would expect to find it here; because of its high specific gravity and the fact that careful washing was the only available method for separating and purifying the portions into which the residues were divided. Boiling the material on which analysis No. III was made with hydric nitrate had no effect upon this point as columbous oxide and metallic tungsten are either only very slowly attacked or not at all acted upon by this agent.

Relative to the probability of the presence of metallic tungsten in these iron bottoms I would repeat the statement that they are closely related to cast iron and others have observed that metallic tungsten may exist as such in cast iron. Further, the result of much labor in an endeavor to obtain columbous oxide directly from a mixture of columbite, magnetite, and stream tin containing wolfram, was a series of iron bottoms which when melted together and subsequently dissolved in hydric chloride yielded a small quantity of a well crystallized residue in which, neglecting a minute quantity of iron, tungsten was the only metal. The crystals were octahedral, apparently quadratic, with some six-sided plates similar in color, luster, and in being pitted to those observed in portions two and three of the residue form the third bottom. Most of the octahedral faces were smooth but on some crystals these faces were depressed at the center. These crystals when kept at a bright red heat for half an hour in an open crucible were only very slightly oxidized and appear to be metallic tungsten.*

As the components of these various products could not be satisfactorily distinguished, even with the aid of the microscope, we are compelled to have recourse to the study of those ratios which remain constant while others vary.

We may divide the results obtained in analyses one and two into two groups, one containing the iron and tin, and the other, the columbium, tungsten, and oxygen. The iron and tin together constitute 25 per cent of the first sample and rather less than 4 per cent of the second, but the ratio of the iron to the tin is the same in each. If we calculate these elements found in each analysis to one hundred we obtain for

* The ignited crystals themselves were not soluble in hot hydric chloride, sp. gr. 1·2, but the ignited mass gave with this salt a yellowish solution which solidified on being poured into a cold beaker, to a buttery mass, which proved to be pure tungstic acid. This is the second instance in which I have found tungstic acid to be soluble in hydric chloride. The statement in Gmelin-Kraut's Handbuch der Chemie, is that "Acids, even concentrated sulphuric acid, do not dissolve it," i. e. WO_3. Its solubility in acids has been observed but once before this so far as I can find, i. e. by J. W. Mallet.

number I: Fe 80·47 per cent, Sn 19·53 per cent, for number II: Fe 81·72 per cent, Sn 18·28 per cent. The ratios obtained for the remaining elements are quite as satisfactory and represented in the same manner are as follows:

No. I.		No. II.	
Cb	49·91	Cb	50·44
W	38·42	W	39·09
O	11·67	O	10·47
	100·00		100·00

The percentage composition required by the mixture 10CbO+4WO is Cb 49·473, W 38·737, O 11·890. The properties of this mixture agree closely with those of columbous oxide especially in burning with incandescence to columbic acid. The presence of the triangular prisms is quite conclusive that the columbium and tungsten are present in separate compounds, which will appear more fully further on.

The two remaining analyses are not comparable to the same extent as those just given, still Nos. III and IV give 1:1·21 and 1:1·22, respectively for the ratios of the columbium and tungsten to the oxygen.

While it is inferable from the results of analysis III that the tungstic acid in the other analyses was derived from the prismatic crystals, the most conclusive proof that these triangular prisms are crystals of a compound of tungsten with only a very little or no iron or tin is afforded by the material designated part I of the residue from the third bottom; for upon being treated with aqua regia in successive portions it yielded upon the first treatment a solution carrying ferric oxide equal to 2·3 times the amount of tungstic acid formed while the second treatment produced an amount of tungstic acid equal to 7·3 times the amount of ferric oxide which went into solution. The residue from the first treatment was very largely made up of these triangular crystals. We conclude from all of this that this hemiprism is the usual crystal form of the compound of tungsten which occurs in these residues. This conclusion is supported also by a comparison of the results obtained in analyses II, III and IV with the respective materials on which they were made. The material serving for analysis No. II was a fine crystalline powder with some triangular crystals; that serving for No. III contained very many of them, while in No. IV I estimated them as forming upwards of 85 per cent of the mass. The results of the analyses are

	II.	III.	IV.
Cb	48·56 per cent.	6·56 per cent.	1·46 per cent.
W	37·64 "	76·12 "	86·64 "

Analyses Nos. I and II give the ratio of 1 : 1 for the atomic ratio of these metals to the oxygen, and Nos. III and IV give approximately the same, from which it appears that we have a mixture of columbous and tungstous oxide in these residues and that the triangular prisms are crystals of the latter.

Tungstous oxide—WO—as thus obtained crystallizes in the hexagonal system, mostly in hemiprisms having a light gray to tin white color, a metallic luster, a hardness greater than glass, and a dark gray streak. Hydric chloride, fluoride, and sulphate, also a boiling solution of potassic hydrate have no perceptible action on it, but hydric nitrate and aqua regia attack it, especially when heated, converting it slowly into tungstic acid. The crystals can be kept under water or exposed to the air at ordinary temperatures without change, but when heated to redness in the air they are gradually converted into tungstic acid; this change takes place without incandescence but is accompanied by a considerable increase in volume, less, however, than that which accompanies the corresponding conversion of columbous oxide into columbic acid which is accompanied by incandescence.

The tungstous oxide was probably formed in this case by the action of stannous oxide, formed in the repeated liquations of the tin, upon metallic tungsten which had been reduced in the original tin charge.

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ART. XXXIV.—*A Sodalite-Syenite and other Rocks from Montana;* by WALDEMAR LINDGREN, *with Analyses* by W. H. MELVILLE.

AMONG the collections in the U. S. National Museum there is a suite of specimens, principally of eruptive rocks, collected in the northern part of Montana, by Dr. C. A. White and Mr. J. B. Marcou during the summer of 1883. The principal localities where the collections were made are the Moccasin Mountains, the Bear Paw Mountains, and Square Butte, near the Highwood Mountains. Rocks from these places have not been previously examined, as far as I know, and it is only proposed in this paper to describe in detail one which appears of particular interest; the general character of the collection, however, may be briefly noted. All of the igneous rocks collected appear to belong to the class of post-Cretaceous intrusive rocks which has such a wide distribution in the Rocky Mountains and which range from the most acid to the most

basic composition. Dr. C. A. White has had the kindness to furnish me with information regarding the occurrence in the field of the rocks and all the statements in the following pages in reference to this are from his unpublished notes.

The Moccasin Mountains form an isolated group about seventy miles southeast from Fort Benton on the eastern side of Judith river. They consist, according to Dr. White, of a central core of eruptive masses, probably laccolitic in character, surrounded by a ring of upturned sediments ranging from the Cretaceous to the Carboniferous. The rocks from the central core appear to belong only to one type. They are light colored, gray or yellowish porphyritic rocks with large phenocrysts of sanidine and soda-lime-feldspar, and smaller ones of brown hornblende; a greenish augite is occasionally seen. The groundmass is always holocrystalline of more or less fine grain and consisting of unstriated feldspar and quartz which sometimes are intergrown in such manner that each quartz grain contains numerous smaller feldspar grains of irregular optical orientation.*

These intrusive rocks from the Moccasin Mountains appear almost identical with the laccolitic masses in the Carboniferous of the Little Belt Mountains and the dikes in the Cretaceous east of Cadottes pass which I have described in previous papers under the name of dacites and diorites.†

Again, very similar rocks have been described in detail by Mr. Whitman Cross from Leadville and other localities in Colorado, and by Mr. Iddings from the Yellowstone Park region. It is apparent that this type of porphyritic intrusive rock is of wide-spread occurrence in the Rocky Mountains; the name of porphyrite or quartz-porphyrite‡ is now usually applied to them.

The Bear Paw Mountains are situated sixty miles northeast of Fort Benton and rise about 2500 feet above the surrounding plains. According to Dr. White, they are largely made up of igneous rocks intruded in Cretaceous strata. The specimens which are taken in the broad valley of Eagle creek at the south base of the mountains, mostly from dikes or dike-like masses, show a very different type from the one just described.

Prevailing is a dark fine-grained porphyritic rock with phenocrysts of greenish idiomorphic augite up to three milli-

* The name of *micro-poikilitic* has recently been suggested by Mr. Iddings for this structure.

† 10th Census, vol. xv, pp. 720 and 731. Eruptive rocks from Montana; Proc. Cal. Acad. Sci., series II, vol. iii, p. 39.

‡ The definition of porphyrite as applied to this type of rocks is given by Mr. Iddings in his paper on "The Eruptive Rocks of Electric Peak and Sepulchre Mountain." 12th Ann. Rep. U. S. Geol. Survey, p. 582.

meters long and flakes of a brown, slightly pleochroic mica with very small axial angle. The groundmass consists mostly of lath-shaped plagioclase crystals together with augite and mica. In some specimens with phenocrysts of olivine and augite the groundmass is glassy and contains no feldspar; this rock approaches closely to certain limburgites. The general appearance of the Bear Paw series and the absence of phenocrysts of feldspar in it points to its connection with the group which Rosenbusch has called the lamprophyric dike rocks.

The suite of specimens collected at Square Butte is of particular interest. Square Butte, which really forms the eastern end of the Highwood Mountains, is situated thirty miles southeast of Fort Benton and eighteen miles nearly due east of Highwood Peak. The rocks from this locality show a close relationship with those from the main group of the Highwood Mountains, and it may perhaps not be amiss to refer briefly to the character and rock types of the latter.*

The Highwood Mountains with their sharp and jagged peaks and ridges stand in isolated grandeur on the monotonous plains twenty miles south of Fort Benton on the Missouri river. They form an oblong group twenty miles from north to south and thirty miles from east to west and their highest peaks rise 3600 feet above the surrounding Cretaceous plateau which here consists of the nearly horizontal black shales of the Fort Benton group. The mass of the mountains is made up of a network of dikes and probably also of laccolitic masses between which are included contact metamorphosed and disturbed remnants of sediments none of which are believed to be older than the Cretaceous. Above the Fort Benton group once rested the whole thickness of the Montana and Laramie formations or at least 8000 feet of sediments. Volcanic activity began at this point at or after the close of the Cretaceous period. Great quantities of igneous rocks were forced into the sediments and on the surface the eruption was probably connected with the phenomena of a subaerial volcano. Subsequent erosion has removed nearly the whole thickness of the softer Laramie rocks, exposing the harder core of the ancient volcano and the abyssal rocks solidified under a pressure of many thousand feet of superincumbent sediments.

The Highwood Mountains are very similar in structure to the Crazy Mountains, also in Montana, recently described by

* The general geology of the Highwood Mountains has been described by Prof. W. M. Davis in 10th Census, vol. xv, p. 697, and the petrography by W. Lindgren, *loc cit.*, p. 729. See also, "Eruptive Rocks from Montana," by W. Lindgren. Proc. Calif. Acad. Sci., series II, vol. iii, p. 40.

Mr. J. E. Wolff,* but the petrographical character of the two volcanic districts is somewhat different.

The intrusive rocks of the Highwood Mountains are in general basic in composition and holocrystalline in structure. There are a few coarsely granular rocks, principally dikes of augite syenites, but a much more common type of rock is of a porphyritic structure and closely allied to the trachytes.†

Augite-trachytes are frequent, usually containing two generations both of the orthoclase and the augite. The latter is characterized by a deep green color and evidently contains an admixture of the acmite molecule. The quantity of augite in these rocks is sometimes very large, and they grade over into basaltic rocks with orthoclase, plagioclase, olivine and augite.

Attention should be called to the great similarity of these rocks with the peculiar intrusive and extrusive masses recently described by Mr. Iddings from the Crandall basin and the Absaroka range in the National Park region.‡

Another interesting type in the Highwood Mountains is that of the analcite-basalts which, with holocrystalline porphyritic structure, consist of augite, olivine, brown mica and analcite. The latter mineral here appears under conditions strongly suggesting a primary origin.

Square Butte and vicinity was not visited by me in 1883, and I am again indebted to Dr. C. A. White for notes regarding it. As already mentioned, it forms the extreme eastern part of the Highwood Mountains with which it is connected by several lower buttes and ridges. The elevation of the flat top, about three-quarters of a mile in diameter, is 5600 feet above sea level according to the maps of the Northern Transcontinental Survey (Fort Benton sheet, U. S. Geol. Survey). The Butte is composed of a light gray eruptive rock with very distinct lamination. In the elevated table land surrounding its base are found several horizontal sheets of a dark gray or black volcanic rock interbedded with black Cretaceous shale belonging to the Fort Benton group. There are three distinct sheets of this dark rock, each about eight feet thick and separated by beds of shale of about the same thickness. Surrounding Square Butte there are numerous dikes apparently radiating from the central mass.

The dark volcanic sheets are represented in the collection by three types. Unfortunately, most of them are very much decomposed. The first is porphyritic and contains as phenocrysts augite of the Highwood type, olivine, usually brown

* Bull. Geol. Soc. Amer., vol. iii, p. 445.

† This term is here used without restriction to surface flows.

‡ The Origin of Igneous Rocks, by J. P. Iddings. Phil. Soc., Washington, D. C., vol. xii, p. 169.

mica, and lastly white isometric crystals up to two millimeters in diameter. The original character of these white crystals cannot be made out as they are completely converted into secondary aggregates. The groundmass, which is quite fine-grained, contains much augite, besides other indeterminable minerals.

The second type is similar to the "analcite-basalts," but the specimens are not fresh and the white mineral is again completely decomposed. This type is more coarsely crystalline and not so pronouncedly porphyritic.

The third type is coarsely granular and in composition approaches the *theralite* described by Mr. J. E. Wolff from Martindale near the Crazy Mountains.

The main mass of Square Butte is represented by a light yellowish grey, rather coarse grained granular rock of miarolitic appearance (No. 28705, U. S. National Museum, Summit Square Butte). Macroscopically it consists of grains and broad lath-shaped crystals of feldspar, often five millimeters long, black glistening hornblende prisms reaching three millimeters in length, and sodalite which appears as small grains of a pale brownish color. Under the microscope the rock is shown to be hypidiomorphic granular and the following constituents are noted in their order of formation: *apatite*, *hornblende*, *orthoclase* (with some *plagioclase*), *sodalite*, and *analcite*.

Fig. 1.

Sodalite-syenite magnified 7 diameters. A hornblende, B orthoclase, C sodalite, D analcite.

The predominant constituent is orthoclase, occurring both as irregular grains and lath-shaped crystals; individuals partly or wholly imbedded in sodalite show terminal faces. Many of

the grains are very clear, but the larger part are somewhat clouded, not, however, by decomposition and the formation of muscovite and kaolin, but principally by irregular and elongated gas inclusions together with others of indeterminable character. Small crystals of apatite, as well as green and brown hornblende microlites, are noticed in the feldspars. A triclinic feldspar with very fine twinning lamellæ in only one direction occurs in intimate, almost microperthitic intergrowth with many of the orthoclase grains. This triclinic feldspar which usually is more pellucid than the orthoclase has every appearance of being albite.

Many of the feldspar grains are corroded in a peculiar manner as shown on the figures and are filled with faintly doubly refracting analcite. The same corrosion has been observed in an augite-syenite from the Little Belt Mountains,* although the enclosed mineral was not then recognized as analcite; a comparison with the Square Butte rock shows beyond doubt the identity of the two minerals. It has also been noted by J. Francis Williams in similar rocks.† This analcite is doubtless derived from the albite. It is a curious fact that although there is abundant sodalite present in the rock it should have remained fresh and undecomposed while the albite was attacked. There are no other zeolites or products of decomposition and it appears as if this conversion into analcite would have taken place very soon after the solidification of the rock. It certainly cannot here be regarded as a product of ordinary decomposition. Prof. Brögger‡ and other authors have shown that analcite, in general, is the earliest of all the zeolites and that it must have been formed at a relatively high temperature, that is, perhaps between 200° and 400°. Friedel and Sarasin§ for instance obtained analcite by heating the constituents of *albite* with water to 400°.

In order to test the character of the feldspars, fragments were introduced into a Thoulet solution. The feldspars began to sink at sp. gr. 2·57 and continued to fall until a sp. gr. of 2·45 was attained. Two portions were subjected to partial analysis:

	Sp. gr. 2·57	Sp. gr. 2·55
Na_2O	6·08	3·88
K_2O	8·91	11·03

It is evident that the first portion is orthoclase with a strong admixture of albite and equally so that the second is a nearly

* Eruptive Rocks from Montana, loc. cit., p. 46.
† Ark. Geol. Survey, 1890, vol. ii, p. 79.
‡ Zeitschrift f. Kryst. u. Miner., xvi, p. 169.
§ Compt. rend. 1883, xcvii, 290.

pure orthoclase. The analcite which penetrates the feldspars is the cause of the lowering of the specific gravity; a mechanical separation of the two minerals is hardly practicable.

The hornblende occurs as slender black prisms bordered by ∞P and $\infty P\bar{\infty}$; terminal faces are not seen. It is idiomorphic both against the orthoclase and the sodalite. The color in thin section is a very dark brown, so dark in fact that in slides of ordinary thickness many crystals are only faintly translucent. The pleochroism is very strong; the rays vibrating parallel to c and b are both very strongly absorbed, producing a dark brown color, while those vibrating parallel to the axis of maximum elasticity are less absorbed with a yellowish brown color, sometimes showing a tinge in green. The axis of minimum elasticity is inclined to the principal axis at an angle not exceeding 13°. In some places the brown hornblende is undergoing a peripheral conversion into a green modification with an extinction up to 25°.* The specific gravity of the hornblende was found to be 3·437. From the characteristics mentioned above the identity with Prof. Brögger's barkevikite† seemed highly probable and to confirm this a quantity was isolated and analyzed.

	I. Square Butte.	II. Barkevik. Analyzed by G. Flink.
H_2O (above 100°)	0·24	
SiO_2	38·41	42·46§
Al_2O_3	17·65‡	11·45
Fe_2O_3	3·75	6·18
FeO	21·75	19·93
NiO	trace	
MnO	0·15	0·75
CaO	10·52	10·24
MgO	2·54	1·11
Na_2O	2·95	6·08
K_2O	1·95	1·44
	99·91	99·64

The mineral differs from barkevikite, an analysis of which is given under II, in containing somewhat less silica and alka-

* The conversion of brown compact hornblende into a green fibrous modification was first observed by Mr. G. F. Becker, in his "Geology of the Comstock Lode," Monogr. III, U. S. G. S., p. 36, Washington, 1882. The same change has been noted by Mr. F. Becke and Prof. G. H. Williams, Bull. 28, U. S. Geol. Survey, p. 45.

† Z. f. Kryst., u. Min., xvi, p. 412.

‡ The titanic acid in (I) is contained in the alumina. The rock carries 0·29 per cent TiO_2 and contains 23 per cent. hornblende; hence, there being no other titanium minerals present, the TiO_2 in the hornblende may be calculated at 1·26 per cent which would reduce the alumina to 16·39 per cent.

§ With some TiO_2.

lies, while the alumina is higher. The low percentage of CaO and MgO and the high amount of FeO show, however, that it is very closely related to it. In the absence of any crystallographic orientation the only way of distinguishing it from arfvedsonite is by its color and streak. I believe this is the first time that barkevikite has been identified in the United States. The hornblende in the *pulaskite*,* described by J. Francis Williams, also a syenitic rock, is probably closely related to barkevikite, but no analysis was made of it.

The sodalite forms irregular grains and partly developed crystals; it is allotriomorphic against the feldspar, but usually idiomorphic whenever bordering on the analcite. It sometimes fills triangular interstices between the lath-shaped feldspars. The period of its consolidation seems here to be decidedly later than that of the feldspar. The cleavage parallel to α 0 is well indicated by the arrangement of very numerous inclusions in part of gas, in part of liquid with very large air bubbles; frequently these inclusions have the form of the enclosing minerals. Small moving bubbles do not often occur. The sodalite is perfectly isotropic and very fresh. Only very locally may a corrosion and decomposition into analcite be observed, such as shown on the large sodalite grain in figure 2.

Fig. 2.

Sodalite-syenite. Magnified 25 diam. A hornblende, B orthoclase, C sodalite, D analcite.

A little chlorite or serpentine is sometimes infiltrated from the hornblende. The sodalite is somewhat unequally distributed through the rock; the figures are taken from places where it

* Geol. Survey of Arkansas, Ann. Rep., 1890, vol. ii, p. 64.

is especially abundant and give a rather exaggerated idea of the quantity of this mineral.

Besides the already mentioned occurrence of analcite in the feldspar it also fills interstices between the feldspar and sodalite grains in the manner shown in the figures. It is very clear and free from inclusions; a peculiarity of it is that contrary to the data usually given its refraction appears stronger than that of the feldspar and sodalite. It always shows a faint double refraction in dark gray and bluish colors and each grain usually divides into several sectors with different optical orientation. The form of the larger grains is triangular or polygonal, being molded by the crystallographic faces of the feldspar and sodalite as shown in the figure. The interpretation of this analcite offers some difficulties. It is not derived from the sodalite; there is no direct proof to show that it has been derived from nepheline; if it is an altered nepheline, then this mineral must have been formed later than the sodalite. No nepheline has been found so far, but it is by no means impossible that other parts of the eruptive mass might contain this mineral. Another possibility is that the analcite fills miarolitic cavities in the rock; it cannot then very well have been derived from any other mineral than the feldspar. The specific gravities of the sodalite and analcite were found to lie extremely close together. They both fell between 2·27 and 2·23. A special and repeated separation was made of this mixture which resulted in the two minerals being obtained in a relatively pure state. The specific gravity of the sodalite ranges from 2·27 to 2·255 while that of analcite extends from 2·26 to 2·24. The two products were then analyzed:

	III. Sodalite.	IV. Analcite.
H_2O (at 100°)	0·45	
H_2O (above 100°)	3·73	(7·07)*
SiO_2	41·56	49·54
Cl	4·79	1·67
Al_2O_3	29·48	25·07
FeO	0·49	0·40
CaO	0·49	0·22
MgO	0·15	0·20
Na_2O	19·21	15·32
K_2O	0·91	0·89
	101·26	100·00
Excess O	1·08	
	100·18	

* By difference.

It is evident that both of these analyses are made of mixed material and equally plain that one of the constituents is sodalite.

In order to calculate approximately the composition of the two minerals let us assume an analcite composed as follows:

$$55SiO_2,\ 23Al_2O_3,\ 13{\cdot}5Na_2O(+K_2O),\ 8{\cdot}5H_2O = 100,$$

and a sodalite containing 37·5 per cent SiO_2. From the silica contents it follows then that (III) contains 76 per cent sodalite and 24 per cent analcite. Calculating further the remaining elements and disregarding for the present the small quantities of Fe, Ca and Mg, one obtains

$$(37{\cdot}50\ SiO_2),\ 31{\cdot}50\ Al_2O_3,\ 22{\cdot}20\ Na_2O(+K_2O),\ 6{\cdot}30\ Cl,\ 2{\cdot}20\ H_2O = 99{\cdot}50$$

which, excepting the high percentage of water, is a normal sodalite.

On the other hand, assuming a sodalite composed as above and an analcite containing 55 per cent SiO_2, it follows that (IV) contains 68 per cent analcite and 32 per cent sodalite, and that the other constituents of the analcite are

$$(55SiO_2),\ 22{\cdot}04\ Al_2O_3,\ 13{\cdot}40\ Na_2O(+K_2O),\ 9{\cdot}37\ H_2O = 99{\cdot}81,$$

which corresponds very closely to a normal analcite. It does not seem possible to avoid the conclusion that a part of the water belongs to the sodalite. Under the microscope the sodalite appears perfectly pure and isotropic and no other zeolites such as natrolite or hydronephelite are present. If all the water belonged to the analcite it would have to contain about 15 per cent H_2O. The amount of H_2O in analcite is, however, very constant and varies only between 8 and 9 per cent. As a matter of fact, the majority of sodalite analyses do contain a small amount of water, and it has been suggested that a certain quantity of Cl may be replaced by (OH).

A quantitative separation of the rock was made and the following figures obtained for which only an approximate correctness is claimed:

66	feldspar.
23	hornblende.
8	sodalite.
3	analcite.
100	

The proportion between albite and orthoclase could not be correctly ascertained on account of their very intimate intergrowth, but from the thin sections and from the separation it was estimated that the rock might contain 50 per cent ortho-

clase and 16 per cent albite. If it is further assumed, for the purposes of a calculation of the rock analysis, that the composition of the two minerals is

	Orthoclase.	Albite.
SiO_2	68	66
Al_2O_3	21	19
Na_2O	11	13
K_2O	--	2
	100	100

the composition of the rock may be calculated as follows:

	Hornblende.	Orthoclase.	Albite.	Sodalite.	Analcite.	Calc. comp.	Rock analysis. V.	Difference.	VI.
H_2O*	----	----	----	----	----	----	0·26	----	----
H_2O†	0·06	----	----	0·16	0·29	0·51	1·51	+1·00	3·49
SiO_2	8·83	33·00	10·88	3·00	1·65	57·36	56·45	−·91	55·76
P_2O_5	----	----	----	----	----	----	0·13	----	----
Cl	----	----	----	0·48	----	0·48	0·43	−·05	----
TiO_2	0·28	----	----	----	----	0·28	0·29	----	----
Al_2O_3	3·77	9·50	3·36	2·52	0·66	19·81	20·08	+·27	21·61
Fe_2O_3	0·86	----	----	----	----	0·86	1·31	+·45	1·65
FeO	5·00	----	----	---	----	5·00	4·39	−·61	4·09
NiO	----	----	----	----	----	----	trace	----	----
MnO	0·04	----	----	----	----	0·04	0·09	+·05	----
CaO	2·43	----	----	----	----	2·43	2·14	−·29	2·26
MgO	0·58	----	----	----	----	0·58	0·63	+·05	0·74
Na_2O	0·69	1·00	1·76	1·72	0·40	5·57	5·61	+·04	6·94
K_2O	0·46	6·50	----	0·08	0·03	7·07	7·13	+·06	5·34
	23·00	50·00	16·00	7·96	3·03	99·99	100·45		101·88
					Excess O.		·10		
							100·35		

The complete analysis of the rock is inserted under V in the third column from the right. The analysis agrees fairly well with the calculated composition in all except SiO_2 and H_2O; the former is very uncertain on account of no complete analysis having been made of the feldspars; the latter is too low in the calculated composition and the rock evidently contains more analcite than 3 per cent. A part of that amount which is not accounted for in the calculated composition doubtless fell together with the feldspars in the separation and some per cent of analcite should be substituted in the 16 per cent of albite. This would bring the calculated analysis closer to the actual composition, as the only effect would be to lower the SiO_2 and increase the H_2O. The analysis further shows that no plagioclase except albite is contained in the rock and also that there is about 0·3 per cent of apatite present.

* At 100°. † Above 100°.

The absence of titanite is remarkable, but as only one specimen has been examined it is not unlikely that this mineral as well as some of the rarer minerals frequently connected with such rocks may be found upon closer examinations of more abundant material.

The analysis agrees in general with that of many nepheline-syenites, but differs from them all in the fact of containing much more K_2O than Na_2O; it has also great similarity with Prof. Brögger's augite-syenite (Laurvikite) except as to the alkalies. Most of all it resembles the nepheline-syenite from the Cape Verde Islands,* the analysis of which is copied in the right column of the table (VI). The latter, however, contains much less K_2O. From the ordinary syenite it differs in the amount of silica, as well as in the low percentage of CaO and MgO.

Only one sodalite-syenite appears to have been described previously; it occurs at Kangerdluarsuk, Greenland, and its minerals have been described in detail by Mr. Joh. Lorenzen,† but I have been unable to find an analysis of the rock. It consists of microcline, arfvedsonite and sodalite, while nepheline is only found in places.

I would finally like to call attention to the striking similarity of the analysis of this rock with those of certain leucitophyres from Rocca Monfina.‡ Under different conditions the same magma, now crystallized as a sodalite-syenite, might have produced a leucite-feldspar rock.

Résumé.—The following rocks are described in this paper:

1) Porphyrites and quartz-porphyrites from the Moccasin Mountains. They are intrusive, holocrystalline rocks of post-Cretaceous age and consist of quartz, orthoclase, soda-lime feldspar and hornblende.

2) Porphyritic, dark colored post-Cretaceous dike rocks from the Bear Paw Mountains. They consist of augite, olivine, biotite and triclinic feldspar and have a general resemblance to the lamprophyric dike rocks of Prof. Rosenbusch.

3) A post-Cretaceous sodalite-syenite from Square Butte. This rock consists of hornblende, orthoclase, albite, sodalite and analcite. No nepheline is found but the interstitial analcite, of which there is 3 per cent, might possibly have been derived from such a mineral. It contains 8 per cent of sodalite.

Washington, D. C., Dec., 1892.

* C. Doelter, Die Vulcane der Cap Verden und ihre Producte; cited in Arkansas Geol. Survey, 1890, vol. ii, p. 81.

† Mineralogical Magazine, vol. v, p. 49, 1882.

‡ Analyses cited in "The Origin of Igneous Rocks," by J. P. Iddings. Phil. Soc. Washington, Bull., vol. xii, p. 199.

ART. XXXV.—*A Basic Dike near Hamburg, Sussex Co., New Jersey, which has been thought to contain Leucite;* by J. F. KEMP.

IN June, 1888, the writer visited the exposures of basic igneous rock, near the Beemerville, N. J., elæolite-syenite and on the materials collected, published a short description in this Journal for August, 1889.* As stated in the paper, the available specimens were much decomposed, and yet as some plagioclase was noted they were called porphyrite. The presence of nepheline was strongly suspected, but although unusually large and abundant apatite appeared, no nepheline could be identified, owing doubtless to advanced alteration.

In the two or three years since the paper was published, there have appeared several descriptions of elæolite-syenite areas elsewhere, and in particular of the basic rocks associated with them; so that we have come to recognize basic dikes as a quite invariable attendant upon this form of plutonic rock. This has proved true of the elæolite-syenite at Magnet Cove, Ark.† Montreal, Canada,‡ and Salem, Mass.,§ in this country; of the exposures in the Serra de Tingua, near Rio Janeiro, Brazil,‖ in the Monchique Mountains of southern Portugal;¶ and near Christiania, Norway.** The basic dikes are analogous to basaltic rocks of various types, including augitite, limburgite, melilite-basalt, feldspar-basalt, and the like, but to preserve the special grouping of dike rocks by themselves, they have received individual names, fourchite, monchiquite, alnöite, etc.

When this literature became available, it was at once seen that the Beemerville dikes or bosses, (they appear more like the latter in instances) were analogous to these, and in the Arkansas Report, (Ann. Rep. 1890, vol. ii, p. 403), they were stated to be practically the same thing as the Arkansas rocks called ouachitite.

In September, 1890, the writer went again to the Beemerville syenite area,†† and was fortunate in learning through Mr.

* On certain Porphyrite Bosses in Northwestern New Jersey, pp. 130–134.

† J. F. Williams and J. F. Kemp, Second Ann. Rep. State Geologist of Ark., vol. ii, pp. 290, 392.

‡ B. J. Harrington, Geol. Surv. Can. 1877–78, p. 429. F. D. Adams, this Journal, April, 1892, p. 269.

§ J. E. Wolff, Geol. Soc. Amer., iii, p. 84.

‖ O. A. Derby, Quart. Jour. Geol. Soc., xliii, 457, and xlvii, 251, (especially 265).

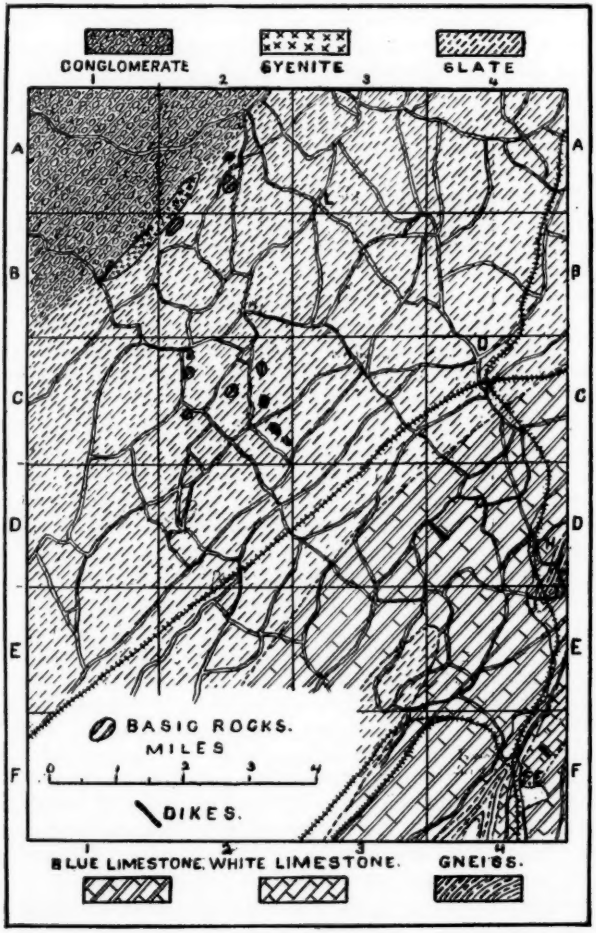
¶ Hunter and Rosenbusch, Tsch. Min. und Petr. Mitth., xi, 455, 1890, and still earlier by L. Van Werveke, Neues Jahrbuch, 1879, p. 451, and 1880, pp. 141–186, but especially 179.

** W. C. Brögger, Zeitschrift f. Kryst., vol. xvi, 1890, p. 79.

†† Elæolite-syenite near Beemerville, N. J., Trans. N. Y. Acad. Sci., vol. xi, p. 60, Feb. 1892.

W. R. Van der Huff, of Deckertown, of another dike, near Hamburg. This was visited and from it a suite of specimens obtained, which are quite fresh, and which show several very peculiar and interesting features. The dike lies much farther

Fig. 1.



away from the syenite, than those earlier described and more than half way to Franklin Furnace, where Professor Emerson found years ago the peculiar mica-diabase.* The accompany-

*B. K. Emerson, this Journal, III, xxiii, p. 376. Still another dike has been discovered by F. L. Nason, at Rudeville, N. J. Geol. Surv. 1890, p. 35.

ing map, figure 1, illustrates the general geology and geography. Referring to the squares, the syenite occurs in B1, B2 and A2. It lies along the contact of the Kittatinny (Oriskany) conglomerate, and the Hudson River slates. The older described, basic rocks are all in the slate and outcrop in A2, B2, and C2. The dike here described is in undetermined, but probably lower Silurian, blue limestone, in D4. The Franklin Furnace dike is in white limestone in F4. Several initial letters are inserted to mark the towns: L, in A3, is Libertyville; B, in C2, is Beemerville; D in C4, is Deckertown; H, in D4, is Hamburg; F, F, in F4, is Franklin Furnace. The basic dikes appear at once to be in a general northwest and southeast arrangement, and it is natural to infer that they represent a series of outcrops along a common line of emergence. The Hamburg dike is on the farm of Lewis Havens (lately Zephaniah Havens) and the farm of Miles Harden lies just over the fence. A roadway runs near it. The dike cuts blue cherty limestone, which strikes N. 60 E. and dips 50 N., while the dike itself strikes N. 25 W., being nearly at right angles with the limestone. There are small veins of quartz along the contact, but otherwise no apparent metamorphism. The width of the trap is 15 to 20 ft. and the outcrop is about 50 yards long.

In the hand specimen, it is a dark rock, extremely tough, and thickly set with biotite. In portions some curious, spheroidal inclusions appear, which form one of the chief points of interest. They vary up to 10^{mm} in diameter and are filled with white minerals. They can be cracked out of the matrix, because they are surrounded by concentric scales of biotite. They attracted attention at once in the field and were brought to the laboratory as one of the features deserving special attention.

In thin section the dike rock is seen to be made up of biotite and pyroxene as its larger minerals, and these are set in a very feebly refracting, or entirely isotropic groundmass, that is chiefly analcite. Throughout the groundmass are abundant ægirine rods, apatite needles, magnetite and occasional plagioclase. In places titanite crystals are extremely numerous and the magnetite likewise shows the usual evidence of being titaniferous. Figure 2 is a drawing of the rock, the outlines of whose crystals were traced with a camera lucida. The endeavor was made to give as characteristic a portion as possible. The specific gravity of the rock is 3·040 to 3·049 as determined on several specimens.

The biotite is the deep brown variety characteristic of the nepheline rocks. It is nearly uniaxial and as noted by Professor Rosenbusch (to whom some specimens of the rock were sent and to whom the writer is indebted for a very kind letter)

it is the same as the mica of the theralites, with which rocks Professor Rosenbusch regards this dike as related.

Fig. 2.

Fig. 2. Micro-drawing of normal dike rock. Actual field 3·5^{mm} in diameter, B, biotite, P, pyroxene, A, analcite. The general shading is uniform for each.

The pyroxene is faint yellow in color and affords extinctions up to 33° as measured. It is apparently identical with the one mentioned in the writer's paper on the elæolite-syenite, as occurring in an elæolite-porphyry (see paper on the Beemerville syenite, p. 66.) The basal sections show the emergence of an optic axis not much inclined to them. The plagioclase is in small rods but is not abundant. The analcite is almost or quite isotropic. It gelatinizes readily and stains a deep tint. Cracks showing the cubical cleavages are often to be seen. If the analcite is secondary after original nepheline, this mineral must have been very abundant. As all the other components of the rock are perfectly fresh, it would indicate that the nepheline has fallen an easy prey to atmospheric agencies.

The spheroidal inclusions offer the point of chief interest. This is heightened because they have been thought to indicate leucite. In the fall of 1890, Mr. O. A. Derby, of Brazil, spent several days with the writer, and on looking over the material from this dike, was at once impressed with its resemblance to certain Brazilian dikes, in which similar spheroidal masses occur, which he has regarded as alteration products after leucite. At his request a specimen was given him and on this are based the remarks upon the rock, which appeared in the Neues Jahrbuch, 1892, ii, p. 153, from Dr. E. Hussak. Dr. Hussak refers to the earlier paper on the "Porphyrite Bosses" already cited, but it should be noted that the materials, on which that contribution

was based, contained no trace of the spheroids, and that they first appeared in the fresher material of this later discovered and hitherto undescribed dike—which were shared with Mr. Derby. Dr. Hussak calls the rock a leucite-tephrite and adopts the view originally taken by Mr. Derby. I have since discovered the same spheroids in some material from the dike in the Buckwheat Mine at Franklin Furnace, but with different mineralogical contents as will be noted later. Inasmuch as the existence or probable existence of so rare and interesting a mineral as leucite in association with the Beemerville elæolite-syenite is an important question, some especial care and deliberation have been exercised in investigating the rock.

As opposed to the leucite interpretation, Professor Rosenbusch, in a personal letter, remarks the perfect analogy which the spheroids have with certain others which characterize the "Kugel-minettes." As is well-known to petrographers, the lamprophyric dikes, that contain especially biotite, orthoclase and some plagioclase and that are called minettes, show a marked tendency to develop in certain cases spheroids or "kugeln." Such have been noted by Cohen* from Odenwald, by Linck† from Weissenberg, and by Liebe and Zimmermann‡ from Thuringia. Very nearly, if not quite, the same thing is figured by Teall,§ in a rock from the island of Car Craig, near Inchcolm, in the Frith of Forth. The rock itself is described as related to the teschenites, a description that fits the Hamburg dike, perfectly. The rocks described by Liebe and Zimmermann are the only ones of the German references of great interest here. Some spheroids (kugeln) they regarded as variolitic or perlitic structures, while others, that, like those of the Hamburg dike, possessed tangential veins of biotite, they rightly inferred could have had neither an amygdaloidal nor a variolitic origin. These latter spheroids were formed of crystals of feldspar irregularly grouped.

In the Hamburg dike the spheroids consist chiefly of analcite. This is illustrated in figure 3, in which nearly the whole is of this mineral. The analcite shows at times the faint cubical cleavage, as is indicated, and again it lacks it. The substance is identical with the general groundmass of the rock. A few minute specks of magnetite were in it, and one feldspar rod. In the upper portion a piece of analcite appeared to have suffered a further alteration to a brightly refracting rim of calcite and other small dots of the same mineral are seen throughout the spheroid. In other spheroids than the one drawn,

* Neues Jahrbuch, 1879, p. 858.

† Idem. 1884, ii, 194. The reference is a review of the original, by H. Rosenbusch.

‡ Jahrbuch d. k. Pr. Landesanstalt, 1885, 178–190, but especially 184.

§ British Petrography, p. 191. Plate xxii, fig. 1.

titanite crystals are grouped about the rims in great numbers. Dr. Hussak also mentions tiny muscovite scales as probably

Fig. 3.

Fig. 3. Micro-drawing of a spheroid. Lettering as in fig. 2. In addition C is calcite, F is feldspar. Actual field 3·5mm.

present in the one examined by him. Around more than half the spheroid are flakes of biotite arranged tangentially, but neither in this nor in others do they entirely surround the kernel, which shades out into the general groundmass. The spheroids so far as observed are always rounded and show no recognizable outlines of the tetragonal trisoctahedron. They gelatinize readily and stain a deep tint with fuchsine. An analysis of several by Professor L. M. Dennis, of Cornell University yielded the results in column I. The water was determined by direct weight. Column II, contains the same analysis, recalculated after the CO_2 of I, had been combined with the necessary CaO, to afford $CaCO_3$, and omitted. This reduces the analysis to a nearer expression of the analcite present.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
H_2O	6·08	6·31	1·46	1·78	8·11	5·01	0·52	0·95
SiO_2	50·52	52·44	55·91	55·06	54·34	55·28	56·48	44·46
Al_2O_3	25·477	26·44	23·88	25.26	23·61	21·21	23·14	30·97
Fe_2O_3	0·413	0·43	3·12		0·12	0·93	----	2·09
CaO	4·05	1·94	1·22	0·60	0·21	3·70	----	0·66
MgO	----		tr.	0·28	----	0·39	----	----
K_2O	3·41	3·54	6·09	10·34	0·66	2·73	19·78	5·91
Na_2O	8·58	8·90	9·55	7·60	12·95	8·93	0·50	15·61
CO_2	1·71	----	----	----	----	----	----	----
Total	100·240	100 00	101·23	100·92	100·00	98·18	100·42	100·65

I. Analysis of spheroids from the Hamburg dike by Prof. L. M. Dennis of Cornell University.

II. Recalculation of I, 3,886 per cent $CaCO_3$ having been taken out.

III. By E. Hussak of "leucite-pseudo-crystals" from Brazilian Foyaite, Neues Jahrbuch, 1892, II, 146.

IV. By J. F. Williams, "pseudo-leucites" from leucite-syenite dike rock. Magnet Cove Ark. Ann. Rep. Dir. Geol. Surv. Ark., 1890, II, p. 270.

V. By Rammelsberg. Analcite from the Cyclopean Islands. Min. Chem., 804, quoted by Dana.

VI. By Nikolayev of massive analcite from Blagodatsk, Russ. Berg. Jahrb., II, 376, 1881. Zeitschr. Kryst., xi, 392, 1886. Dana's Mineralogy, new ed., 597.

VII. By Rammelsberg, Leucite of Vesuvius. Pogg. Annalen, xcviii, 142.

VIII. By Smith and Brush, Elæolite from Magnet Cove, Ark. This Journal, II, xvi, 371.

A comparison of II and V shows at once that the spheroids are practically analcite, for while the lime and alumina are high, and the silica rather low, the correspondence is extremely close, when it is remembered, that some little plagioclase is confessedly present, and a few other small impurities. The parallel between the soda and potash, and those of the massive analcite, Analysis VI, is very close. In respect to a change from leucite, we have to account for an immense accession of soda, and as regards the corresponding alteration from nepheline, a much smaller accession of potash. But the analysis of elæolite from Magnet Cove gave the alkalies in about the same ratio. In either change outlined above the alkalies have decreased in amount more than is compensated by the increase in water. On the whole, other things being equal, the analysis rather favors original nepheline, than original leucite.

Analcite as an alteration product is well known from both nepheline and leucite. Abundant literature on both changes is cited by Rosenbusch, and hardly needs repetition. It is especially interesting to mention the occurrence of this mineral in the teschenites, in which it is generally regarded as secondary after nepheline. The possibility of both these changes may be taken for granted.

On the one hand in the feldspathic rocks (minettes of Germany and in the mica-diabase or kersantite from Franklin Furnace), what appear to be essentially the same structural phenomena as the spheroids, occur with feldspar centers and biotite rims. No one has thought of leucite in these connections, nor does there seem any reason to do so. A group of feldspar crystals, irregularly aggregated have formed, and have attracted to their common border a tangential rim of biotite.

It is quite conceivable that nepheline crystals, with more or less feldspar might do the same, and subsequently alter to analcite.

On the other hand leucitic rocks in Brazil and elsewhere as cited by Hussak, present analogous phenomena. Leucite often tends to attract tangential rims and inclusions. It is, however, a mineral of comparatively restricted occurrence and although recently demonstrated in two new localities, Arkansas and Brazil, in association with elæolite-syenites, the probabilities are against it until unquestionably shown.

In the writer's judgment the question cannot be settled without the discovery of perfectly fresh material either of nepheline or leucite in the spheroids, and pending this, that the determination of the rock as a leucite-tephrite is premature, and should only be suggested as a future possibility. But if it should be demonstrated in New Jersey in association with the elæolite-syenite, it would form a most interesting addition to the geology of the region.

Geological Department, Columbia College.

Art. XXXVI.—*Underthrust Folds and Faults;* by Eugene A. Smith, University of Alabama.

In the normal Appalachian fold, it has been repeatedly pointed out that one side of the fold is much steeper than the other, and that these folds have been produced by the action of a force coming from the direction of the Atlantic, and hence from the east and southeast, is very generally admitted. In the great majority of cases these folds have been pushed or lapped over towards the northwest, so that the more gently sloping strata dip toward the southeast, while those with the steeper dip are turned towards the northwest. So also when a fault occurs along the steeper side of the fold, the strata on the southeast of the fault are thrust up over those on the northwest side. Such faulted folds have been called by a variety of names; *overfaults*, *faulted overfolds*, etc., and the general term *overthrust faults* would also apply to these, especially where the over-riding has been very considerable.

A few instances have come under observation in Alabama, and are mentioned also in other States, where the steeper side of the fold lies to the southeast, and the more gently inclined side to the northwest, and where the fold has been faulted, the gently inclined northwest dipping strata *seem* to have been thrust up over the more highly inclined beds to the southeast.

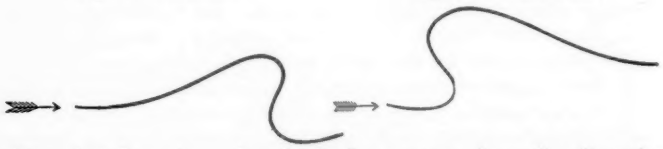
It was suggested by Mr. A. M. Gibson of the Alabama Geological Survey some years ago, that this peculiar structure, the

very reverse of what we commonly see in the Appalachian region, was to be explained on supposition that in the folding, instead of the arch limb of the fold being, as is usually the case, thrust up over the trough-limb, and lapped over toward the northwest, the trough-limb was thrust under the crest or arch-limb, the effect being the same as if, with a force acting from the northwest, the fold had been lapped over in the usual way, i. e. in the direction towards which the force was exerted, or towards the southeast. Inasmuch as we could not easily account for a force acting from the northwest, and since this class of folds has demonstrably a common origin with the folds of the regular Appalachian type, it has seemed to me that the above explanation is the true one.

In the Appendix to Squires's Report on the Cahaba Coal Field, I have discussed this type of structure, and have spoken of the fault as a *reversed thrust fault* in contradistinction to the thrust fault of the normal type which so greatly prevails in the Appalachian region.

I have since thought that another name, which would more clearly point to the mode of formation, would be preferable, and therefore suggest the following terms, *under fault, faulted under fold, underthrust fault*, as applicable to this type of structure. These terms correspond with those used by Margerie and Heim in describing the common type of thrust fault. In speaking of the causes that determine the direction towards which a fold is overlapped, these authors say,* "Der Sinn, in welchem eine Falte geneigt oder überschoben ist, hängt nicht direct von der absoluten geographischen Richtung des einseitigen Schubes in diesem Stück Erdrinde ab. Verschiedene locale Umstände bedingen die Richtung der Faltenneigung. Wenn, z. B. die Basis beiderseits einer beginnenden Falte ungleich hoch ist, so ist die Falte geneigt, sich nach den tieferen Seite ueberzulegen . . . . Wenn die Falten einer Zone nicht mehr aufrecht sind, findet man fast immer die grosse Mehrzahl derselben in gleicher Richtung geneigt oder übergelegt."

Fig. 1. Overthrust. Fig. 2. Underthrust.



The sketches given, in which the arrows show the direction of the folding force, will serve both to illustrate the remarks of Margerie and Heim just quoted, and to show that the two types of structure under discussion may result from the action of the same force acting under slightly different conditions.

* Die Dislocationen der Erdrinde, p. 81.

ART. XXXVII.—*The Cretaceous Formations of Mexico and their Relations to North American Geographic Development;* by ROBERT T. HILL.

MEXICAN geology has been little studied in the light of the broader problems of continental development. In this paper it is proposed to present a few facts in its Mesozoic history which bear upon this relation and are based upon fragmentary literature and upon the observations of the author.

Mexico is a southern geographic continuation of the Cordilleran region of the United States. It consists of an interior plateau or basin enclosed upon the coastal sides by groups of marginal Sierras which are comparable to, although not genetically identical with, the Rocky Mountains and Sierra Nevada systems of our own country. These are known as the Sierra Madre of the east and the Sierra Madre of the west respectively; they unite into a common mass and terminate near the longitude of the City of Mexico. The profile of the southern union of the Cordilleras was the origin of the popular conception that the interior of Mexico is a great plateau; as several writers maintain, it is, really, an intra-mountain basin region between the crests of the Sierras, analogous to and continuous with the Great Basin of our own southern border. The present coastal plains of Mexico are but slightly developed and will not be discussed here.

The geological formations of Mexico may be classified in four general groups: 1. The Pre-Cretaceous rocks which were more or less completely buried beneath the earlier Cretaceous sedimentation and except possibly in Sonora are now only slightly exposed by the erosion of the later formations. 2. The two Cretaceous marine formations which constitute the prevailing sedimentary rocks of all the mountain structure. 3. The Post-Cretaceous eruptives which occur in associations with the Cretaceous formations in the mountain structure. 4. The detrital fresh water deposits which cover the intra-mountain plains and valleys. Of these the events connected with the Cretaceous and early Eocene history of Mexico are the most important.

Two contributions have lately been published upon the occurrence and relations of the Cretaceous formation in Mexico, both of which were founded upon personal observations by the writers in the southern half of the Republic. They differ widely in their conclusions, however, and show that their authors were not entirely familiar with the sequence of the

American Cretaceous beds so harmoniously developed in northern Mexico and in the Texas region. The first of these papers is the excellent monograph by Drs. Felix and Lenk, and summarizes the occurrence of the Cretaceous formation in Mexico as follows:* "The Cretaceous formation in Mexico is divided into two parts. 1. The Upper part (the 'Hippurite' limestone) is characterized by many Hippurites and Radiolite-like forms and numerous Nerineas. This is principally thick light gray sometimes flinty limestone. 2. Below this (they note no break) are light blue-gray sometimes black limestones with local intercalations of marly layers," which we shall hereafter allude to as the Monopleura beds of Tehuacan. The uppermost of these formations or 'Hippurites' limestone they do not describe at length, but passingly refer it to the Upper Cretaceous. The lower or Monopleura beds of Tehuacan, they refer to the Neocomian.

The second paper is by Prof. Angelo Heilprin† of Philadelphia, who, without giving any distinct subdivision or stratigraphic details recognizes only the Hippurites limestone and opposes the careful determination of the Neocomian by Felix and Lenk by saying: "No unequivocal deposits of Lower Cretaceous age—as equivalent of the Gault, Neocomian, etc., have yet been discovered in the Republic; the Mexico deposits represent a horizon not lower than the Cenomanian while the great bulk of the formation is of Turonian and Cenomanian age."‡

The diverse conclusions of these two papers can be explained, as I ascertained in Mexico, upon the ground that neither saw the regions of the full occurrence of the Cretaceous formations of Mexico or the sequence and relations of their divisions.

At most they describe only two of the many horizons in the great sequence of the Lower Cretaceous beds while the equally important but distinct Upper Cretaceous formation or Meek and Hayden series entirely escaped their observation.

*Beiträge zur Geologie und Paleontologie der Republik Mexico, von Dr. J. Felix und Dr. H. Lenk: in two parts, Part I, Leipzig, 1890; Part III, Stuttgart, 1891 (Part II not published).

†The Geology and Paleontology of the Cretaceous Deposits of Mexico, by Prof. Angelo Heilprin, Proc. Philadelphia Academy of Natural Sciences, 1890, pp. 445–469.

‡Prof. Heilprin also concludes that "No true Lower Cretaceous deposits exist or have so far been identified in either Arkansas or Texas, the Lower Cretaceous, so-called (Comanche Series, etc.) being not older than the Cenomanian (Middle or Upper Cretaceous)." I cannot here discuss this conclusion of Prof. Heilprin's concerning a region he had not seen and with whose unpublished paleontology his writings show unfamiliarity. While the upper part of the Comanche Series is undoubtedly of Middle Cretaceous affinities he seems unacquainted with the existence of the Lower Trinity division with its Glen Rose fauna of Neocomian mollusks and Potomac, or Wealden, plants.

The Lower Cretaceous Formation.

The Mountain Limestone.—The most common and striking material in the composition of the Mexican mountains is the firm stratified limestone which, with the eruptive rocks, forms the chief mass of all the Sierras. It constitutes the prevalent sedimentary rock of nearly all the mountains and in the southern States extends in intermittent patches from ocean to ocean. Its strata produce the peculiar scenic effects of the mountain topography and its products are the principal material of the later Basin deposits. Lithologically the lime stone consists of blue and grey, sometimes nearly black, beds of great hardness and density, and indistinguishable lithologically from the Paleozoic limestones of the Silurian and Carboniferous formations of the European and Appalachian regions to which they have frequently been referred from this resemblance.*

The strata vary in thickness from a few inches to a hundred feet. They are so broken and distorted by the mountain structure (fig. 1) and disconnected by the concealment of the

1.

Example of folding of Comanche limestone in Eastern Cordilleras.—Section northwest of Monterey.

basin deposits that it is impossible to give an idea of their total thickness or to obtain a complete section of the series in any one locality. In the eastern Sierra Madre in the valley of Miquehuana where the base of the series was studied by Mr. McGee and the writer, twenty thousand feet of the limestone could be seen in succession in the continuous strata between that point and the Hacienda El Carmen to the westward, all of which was only the lower portion of the great formation. This enormous thickness of the mountain limestone is further indicated by the frequent sections of 5000 feet of portions of the formations often visible in the tilted mountain fronts. Even at the Rio Grande near Presidio del Norte the same limestones as shown by White, attain a thickness of at least 4000 feet.† The persistent characteristics of this limestone with

* The details cannot be given here of the innumerable references of the Cretaceous mountain limestone to Paleozoic age. Nearly always it was mistaken for Silurian or Carboniferous by mining engineers, and early writers on the country. With the exception of certain localities in Sonora given by R. Remond, it is exceedingly doubtful if there are any limestones in Mexico of Paleozoic age.

† This Journal, xxxviii, p. 440, 1889.

abundant paleontologic evidence show that it all represents the same great geological formation of Lower Cretaceous age instead of Upper Cretaceous and Paleozoic age, as frequently asserted, and that it is the southern continuation of the greatly altered, thickened and folded beds of the more chalky limestones of the Comanche Series of the Texan region.

The latter can be continuously traced from the region of their typical occurrence in the sub-coastal plains of central Texas to the mountains west of the Pecos (notably the Quitman mountains) where they are intensely folded and altered from their white chalky aspect into the firm blue limestones above mentioned. This limestone becomes the characteristic mountain rock from Trans-Pecos Texas southward into Mexico where they have been seen by the writer in the mountains in the States of Coahuila, Chihuahua, Nueva Leon, Tamaulipas and San Luis. From the writings of many authors the wide extent of the "Hippurite limestone," as it is called by Heilprin, can be traced over the States of Sonora, Coahuila, Nuevo Leon, San Luis Potosi, Hidalgo, Vera Cruz, Puebla, Mexico, Morelos, Guerro, Jalisco, Queretero, Colima, Aguas Calientes, and Mihoacán, which with the northern border States previously mentioned and Trans-Pecos, Texas, makes its distribution very general over the Republic of Mexico. From the abundant paleontologic evidence there is no doubt but the outcrops in northern Mexico are identical with similar masses described in the southern end of the plateau region by Barcena, Castillo, Virdet, Heilprin, and Felix and Lenk.

Owing to the great alteration the limestone has undergone the fossils, with the exception of a few genera, are usually much obliterated or converted into masses of calcite, but in most cases the form of some familiar Gryphæa, Exogyra, Nerinea, or Rudistes of the Comanche series can be determined. This alteration of the chalky Cretaceous rocks of Texas into the Paleozoic-looking limestone of northern Mexico was first noted in this Journal by Kimball* who called attention to the fact that the mountain limestones of northern Chihuahua were of Cretaceous instead of Paleozoic age as had been asserted by Wislizenus,† and others.

Subdivisions.—Notwithstanding the wide distribution of this formation throughout Mexico no detailed section of it has been presented and no attempt made to define its subdivisions with the exception of the recognition by Felix and Lenk of the two horizons: the "Hippurites" limestone and Monopleura (Tehuacan) beds above mentioned; while the latter

* Notes on the Geology of Western Texas and of Chihuahua, Mexico. This Journal, Nov., 1869.

† Quoted by Kimball.

division has escaped the observation of the other writers. Not only has the mountain limestone of Mexico these two subdivisions but I have found all the broader divisions of the Comanche Series represented in it.

The so-called "Hippurites limestone," however, may be accepted as a datum from which to trace the sequence of the overlying and the underlying horizons as shown in the table on page 324. Heilprin and other writers describe its characteristic fossils as consisting of the "Hippurites," Radiolites, and Nerineas—genera which do not range higher in the Comanche Series than the Caprina limestone of Shumard with which horizon the Mexican "Hippurites" limestone is largely identical.

The Tehuacan or Monopleura beds which Felix and Lenk show underlying the "Hippurites" limestone in Puebla are a distinct lower horizon of the Comanche series to which the writer has recently called attention in the Texas region under the name of the Glen Rose beds of the Trinity division.* From the lower bed they report twenty-eight genera of invertebrates (forty-six species) characterized by the corals. Pleurocenia, Cladophyllia and Astrocenia; a single echinoderm (Cyphosoma) and the Mollusca: Monopleura, Nerinea, and Tylostomas of the *Natica pedernalis* type. All these genera are abundantly found in the Texas Cretaceous and with the exception of Cyphosoma only in the Fredricksburg and Trinity or lower divisions of the Comanche Series and are its characteristic distinguishing forms. In both Texas and Mexico they occur below the "Hippurites" or Caprina limestone, as described in Mexico by Felix and Lenk, and under similar stratigraphic conditions except that in Mexico the limestones have been more altered by mountain movements. The molluscan genera are all strongly characteristic of the Neocomian of Spain and Portugal. These Monopleura beds are near but not quite at the base of the Mexican Cretaceous; northward they outcrop in several places. The writer has seen them ten miles east of Bustamente, in Nuevo Leon, on the Tropic of Cancer, and in the Santa Rosa mountain mass of Coahuila. Near the first mentioned locality about ten miles to the northeast in the valley of Miquehuana they are underlain by a series of still lower beds between which there is no stratigraphic demarcation. These lower beds consist of alternating strata of arenaceous calcareous clays becoming pack sands with quartz pebbles towards their base and rest unconformably upon the early Mesozoic red beds. These basement strata of the Comanche Series in Mexico strongly resemble in composition,

* The Comanche Series of the Texas Arkansas Region, Bull. Geological Society of America, vol. ii, pp. 503–528.

arrangement and littoral characters the Trinity beds of the Comanche Series in Texas, but contain one genus, Rhynchonella, and many different species including several described by Felix and Lenk from southwest of Tlaxioco including *Hoplites tenochii*, *H. neocomensis* D'Orb., *Tylostoma princeps* White, and a large Terebratula very much resembling the form figured as *Inoceramus montezumi* by Felix.

Similar basement beds of the mountain limestone are reported at Catorce and near San Luis Potosi. From the latter locality Nikitin has noted* a fauna resembling that of Miquehuana, but also containing the California and Russian species of Aucella and refers the beds to the upper Jurassic. Near Bustamente these basement beds are metamorphosed into schists owing to the intense folds of the mountain as seen by McGee and the writer.

Felix presents strong arguments for the Cretaceous age of the basement beds, notwithstanding the somewhat Jurassic facies. The basement Trinity beds of the Texas region are clearly the Wealden phase of the Neocomian and these Miquehuana beds are this southward continuation and confirm the fact that the great littoral of the subsiding land in earliest Cretaceous time advanced from the south northward.

The "Hippurites" limestone is not the top of the Lower Cretaceous formation in Mexico, much less the top of the Upper Cretaceous or the equivalent to the Upper Cretaceous of the United States as supposed by Drs. Felix and Lenk, for in northern Mexico at various places I have found it overlaid by the beds of the Washita division of the Comanche Series and this in turn overlaid by the Upper Cretaceous of Meek and Hayden. Near Monclova and Santa Rosa in Coahuila the Washita beds appear as thinner limestone flags and shales overlying the lower limestones and contain the characteristic gryphæas and ammonitidæ of the division. The beds of this division cross into Mexico at several places along the Rio Grande. Opposite Del Rio Texas the *Exogyra arietina* zone of the Denison beds of the Washita division extends far into Mexico. West of El Paso at the international boundary the beds of the Washita limestone division occur on both sides of the river, the famous pass of the Rio Grande at that point being in rocks of the Fredericksburg and Washita division. The Washita beds here include both the Fort Worth and Denison subdivisions and are largely developed in the mountains of northern Chihuahua. Gabb† in 1863, before the stratigraphic identity of the Comanche Series had been made known, recognized the extension of the Texas Cretaceous into

* Jahrbuch für Mineralogie. 1890, ii, pp. 273–274.

† Geological Survey of California, vol. ii, Sec. III, p. 255.

Sonora from a collection of fossils made by Remond. The fossils are the characteristic fauna of the latest or Washita division of the Comanche Series and resemble the variations seen at El Paso and Juarez and throughout the northern littoral of the latest beds of the Comanche Series and belong neither in the Upper Cretaceous formation nor below the Caprina (Hippurites) limestone, as Prof. Heilprin indicates in the paper previously mentioned.

From these data it is evident that the three prominent stratigraphic divisions of the Comanche Series are recognizable in Mexico as in Texas and when the whole region is studied more detailed resemblances of horizons will be discovered.

Age and Homotaxial relations of the Comanche Series in Mexico and Texas.—The diverse opinions concerning the age of the Mexican Cretaceous have been indicated. Felix and Lenk maintain the Neocomian age of the Tehuacan beds and have little to say concerning the so-called "Hippurites" limestone. Most of the Mexican geologists speak of the Hippurites limestone as probably Upper Cretaceous. Prof. Heilprin emphatically maintains the Upper Cretaceous age not only of the Mexican but of all the Texas Cretaceous. This conclusion is based upon the same evidence that caused Dr. Rœmer to make the same mistake in Texas, to wit: the occurrence of the alleged "Hippurites" and Nerineas in the limestone, and Prof. Heilprin's mistaken idea that the writer of this paper holds that the faunas of the Fredericksburg and Washita divisions of the Texas section represent the Neocomian instead of the Glen Rose and Trinity beds, with the faunas of which he (Prof. Heilprin) is evidently unfamiliar inasmuch as they have not been fully published. The writer has endeavored to reserve his views on the homotaxial relations of the North American Cretaceous for a future and exhaustive publication and can say but little concerning them now. In the first place the genus Nerinea which Prof. Heilprin and others consider a characteristic genus of the European Senonian, ranges in Europe from early Jurassic time to the top of the Cretaceous, while in America it extends no higher than the Caprina limestone of the Fredericksburg division of the Lower Cretaceous, not a single species appearing in the great Upper Cretaceous or Meek and Hayden section of the United States. Furthermore this genus has many sub-generic features each with its peculiar stratigraphic range and all the species described from Texas by Rœmer and Conrad and from Mexico by various writers are of the characteristic early Cretaceous type. The occurrence of the alleged "Hippurites," however, prevented Rœmer, Heilprin and others from understanding the true position of these beds, notwithstanding the testimony

of the associated faunas. This genus is characteristic of the Upper Cretaceous of the world, but unfortunately there are no true Hippurites in the Lower Cretaceous of the United States while their occurrence in Mexico is not proven. All the species so-called belong to the lower ranging genera Sphærulites and Radiolites which in Europe especially in Portugal* have the identical position they have in the Texas-Mexican region, i. e. they occur in a narrow zone between the true Monopleura and Caprina beds of the Neocomian and the Gault just as it ranges in Texas between the Monopleura and Caprina beds of the Glen Rose (Neocomian) and the Washita (Gault) division. Dr. Rœmer distinctly states in his description of "*Hippurites*" *texanus* that he is in doubt whether to refer it to the genus Hippurites or Radiolites, and from careful studies of abundant material in my collection it can be seen that the genus is clearly not Hippurites, but has strong resemblance to the Sphærulites of Portugal.

Felix and Lenk in their careful presentation of the Tehuacan or Monopleura beds (Glen Rose beds of my Texas section) show beyond doubt their Neocomian equivalency, and refrain from correlation of the "Hippurites" limestone with the beds of northern Europe.†

If those who doubt the Neocomian position of the faunas of basal half of the Comanche Series will compare my unpublished collections in the possession of the Texas Geological Survey and at my residence in Washington with the beautiful Cretaceous faunas of Portugal as illustrated by

* The so-called "Hippurites" of the Texan (Comanche) Cretaceous are entirely different in specific characters from the well known Hippurites of the Upper Cretaceous of Europe, but are of the genera Sphærulites and Radiolites of Lamarck which in Europe begin in the Lower Cretaceous. It is unfortunate that no systematic study of the biological relations of the American forms has been attempted None of the aberrant molluscan forms like Monopleura, Requienia, Plagioptychus, Caprina, Rudistes, and the alleged Hippurites range higher in the Texan Cretaceous than the Caprina limestone of the Comanche Series and only the entirely distinct generic form called *Radiolites Austinensis* type (Rœmer) has been found in the Upper Cretaceous, while no Hippurites especially of the European type of *H. cornu-vaccinum* have not been found in America.

† Dr. Rœmer, who committed the same error of placing the "Hippurite" bearing Lower Cretaceous of Texas in the Upper Cretaceous of Europe as others who have visited Mexico are now doing with the Hippurites limestone of that country, also wrongly concluded that the Monopleura fauna sent him from near Austin was from the Upper Cretaceous limestone instead of from the Caprina limestone and Glen Rose beds. See "Ueber eine durch die Haufigkeit Hippuriten Artigen Chamiden ausgezeichnet Fauna der Ober Turonienkreide von Texas. Paleontologischen Abhandlungen. IV Band, Heft 4. Berlin, 1887. Reviewed in this Journal by the writer in vol. xxxvii, 1889, pp. 318–319. Although admitting that it was different from anything he had known in Europe under the impression that it came from the Austin chalk, which has Turonian facies, he entitles it a Turonian fauna and so describes it. In all European paleontological treatises, notably Zittel and Steinman, these are shown to be characteristic genera of the Neocomian.

Choffat* they will no longer doubt the homotaxial identity of the beds but will be astonished at the wonderful and striking generic identity. The fossil beds of the Washita division or upper part of the Comanche Series from which Prof. Heilprin draws his conclusion that there is no Lower Cretaceous in America are Gault, and not Cenomanian as he alleges, although Marcou referred them to the Neocomian.† Until the writer's paleontological data can be published in full it will be difficult to eradicate the existing erroneous impressions concerning the North American Cretaceous but he strongly maintains that we have in this country in the Atlantic sedimentation of both Cretaceous Series a complete representation of the principal divisions of the Cretaceous period in Europe, presenting a remarkable homotaxial resemblance in many of their subdivisions, and which, instead of upsetting the canons of paleontologic and stratigraphic laws, as has been maintained, verifies the great principle that sedimentation and life on both sides the Atlantic basin presented in Cretaceous times the same generic resemblances and specific variations that it has in all time and that it does to-day, and that the American Cretaceous formations laid down in the open Atlantic waters present far more intimate resemblances to those of similar deposition in Europe than they do to those of the Pacific border only a few miles distant.

It is evident that the Lower Cretaceous or Comanche Series in Mexico verifies some of the principles already announced concerning it in our own country, to wit: that the deposits there are the deeper water sediments of an oceanic border which had its littoral across the southern end of our own republic, and that they record the progressive encroachment from the southward of the sea upon the Pre-Cretaceous (Jurassic) North American land accompanied by subsidence of the latter. As shown by the rapid shallowing of the sediments in the Washita sub-epoch at the close of Comanche time the profound Lower Cretaceous subsidence reached its culmination during the Fredericksburg sub-epoch and the northern littoral ferruginous beds of the Washita division probably marked the northern border of this Lower Cretaceous or Comanche ocean. This rapid elevation at the close of the Comanche also explains the disappearance of the aberrant Chamidæ and Rudistæ from sediments of later age in the Comanche series than the Caprina limestone, while some of the forms continue to the top of the Gault in Europe.

* Recueil de Monographies Stratigraphiques sur le Système Cretacique du Portugal, par Paul Choffat. Lisbon, 1883.

Extent and History of the Comanche Sedimentation.

The Lower Cretaceous deposits of Mexico extend from the Pacific to the Atlantic and clearly show that during the Comanche sub-period the waters of the two oceans were united and separated the north and south continents into two islands. The southern shore line cannot be minutely traced at present owing to our indistinct knowledge of South American geology, but there is abundant evidence to show that it covered much of the western coast of Peru, Chili, Bogota, and the northern States of South America reaching far into the present area of Andean uplift against the nucleal Archæan and Paleozoic area of that continent, as shown by the occurrence of the typical and peculiar Comanche series, *Schlœnbachia peruvianus*, *Buchoceras pedernalis*, *Gryphœa pitcheri*, *Exogyra texana*, *Patellina* (*Orbitulina*) *texana* and other forms. The Comanche sedimentation extended into northeastern Brazil where its typical fauna has been described from Sergipe by Hyatt* but it does not appear in more southern faunas described by White.

The North American border of this Comanche sedimentation can be definitely located around the coastward margin of the old Appalachian region to near Marietta south of central Indian Territory, but west of this point it can be located at only widely separated places because of the overlapping of the Great Plains and basin formations and the disturbances of the Cordilleran region. In northeastern New Mexico the thin littoral beds of the Comanche are exposed in the strata of Tucumcari Mountain and the adjacent Llano Estacado.† They are next revealed at El Paso where the attenuated and highly tilted beds again outcrop against the foot of the Organ and Monument Mountains on both the Mexican and American sides of the Rio Grande. The most western localities recorded are Ariviche, and Sahuaripa in Senora from where Gabb described its characteristic uppermost or Denison fauna. Except a locality described on the southern line of Kansas no trace of the great Comanche sedimentation has been found and every possible interpretation of the littoral sediments shows that an adjacent land area must have existed over all the Appalachian Great Plains and Cordilleran areas north of a line connecting these points during that epoch, as shown upon the accompanying map.

The central portion of the Mexican plateau where the Comanche Series attains a thickness of more than twenty

* Mentioned on pages 385–393 of Hart's Geology and Physical Geography of Brazil.

† See "On the Occurrence of Artesian and other Underground Waters," etc., by Rob't T. Hill. Final Report Artesian and Underflow Investigations. Senate Doc. 41, 52d Cong., vol. iii, p. 129, Washington, May, 1892; also Third Annual Report Texas State Geological Survey, pp. 152–154. Austin, Sept., 1892.

thousand feet was apparently the medial part of the wide oceanic strip that separated the two American continents in early Cretaceous times and probably the region of greatest deposition. This early Cretaceous subsidence and the accompanying accumulation of sediments was so great as to almost obscure the pre-Cretaceous history of the Mexican peninsula for to-day there are but few places where these limestones, even though aided by the enormous disturbance, have been eroded through to the pre-Cretaceous floor; yet by and of these there is enough evidence to show that the Mexican peninsula had its outline in even earlier geologic time.

The second great event in the history of the Mexican Cretaceous was the elevation of the sea-bottom and the return to land conditions of the region at the close of the Comanche sub-epoch,—an event most important in the interpretation of the history of all the American Cordilleran region and one which has been overlooked owing to the more distinct land making after the close of the Upper Cretaceous. The evidence of this mid-Cretaceous land is: (1) The unconformable deposition of the Upper Cretaceous upon the Comanche Series and consequent discordant overlaps of its western margin. (2) The entirely different outline of the western littoral of the Upper Cretaceous deposits of the Atlantic deposition in the Cordilleran region as shown upon the map, showing that there had been disturbances of the continental area in the Cordilleran region between the intervals of their deposition. (3) The evidence of an extensive land area during Upper Cretaceous time throughout the great basin region of Mexico and the United States, from which was derived the vast accumulation of Upper Cretaceous littoral plant-bearing sediments along the eastern margin of this mid-Cretaceous land. The entire dissimilarity and otherwise inexplicable difference between the faunas of the Atlantic and the Pacific Upper Cretaceous sedimentation south of the Canadian border indicate a continental barrier between them in Cretaceous time.

S. F. Emmons* has recognized in the Colorado division of the Rocky Mountains several areas of what he calls "Jurassic land" and cotemporary movements. These may have extended into the early Cretaceous, for the earliest marine datum of subsidence in that region by which he was able to fix the date of this land area was the basement littoral of Dakota of the Upper Cretaceous.

Between the two epochs the ocean over the Texan region no doubt receded nearly to its present outline as shown by the area traversed by the Dakota littoral from eastern Texas to

* Orographic movements in the Rocky Mountains, Bull. Geol. Soc. Am, vol. i, pp. 245–286.

Wyoming, preceding the Upper Cretaceous subsidence which covered the Great Plains and Rocky Mountain region, while the heart of the Great Basin and the central part of Mexico remained above sea level—apparently a continental divide traversing the heart of the entire central basin region of the Cordilleras from Tehuantepec to the British boundary—and possibly causing the great difference between the marine molluscan faunas of the Pacific region and the Atlantic during Upper Cretaceous times. This seldom appreciated and little understood western continental strip represents to the writer a most important stage in geological history, although but little topographic trace of it remains, for it was this land that furnished the vast sediments accumulated along its eastern front in Cretaceous and Laramie time which were folded up in the last grand epoch of Rocky Mountain making.

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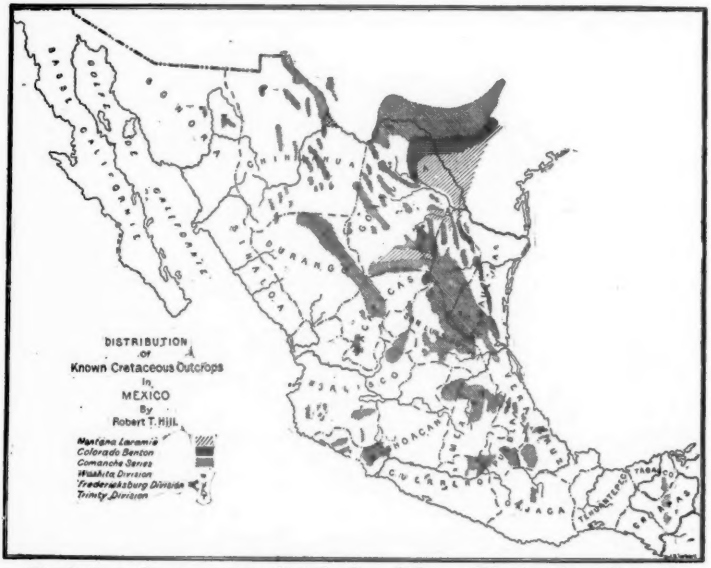

The data on above map are adapted, after slight modification, from Señor Antonio Castillo's excellent Geological Map of Mexico. Mexico, 1889.

The Upper Cretaceous Formation in Mexico.

All writers on the Cretaceous formation in southern and central Mexico have assumed that the mountain or "Hippurites" limestone was the top of the Cretaceous series of the country and have seemed unaware of the existence above it in northern Mexico of the true or Upper Cretaceous formation,

or Meek and Hayden's series, entirely different in lithological and paleontological aspects. Dr. C. A. White and the writer have frequently mentioned this formation in the Rio Grande region, but no attempt has been made to clearly define its geographic limitations.

In distinction from the characteristic mountain limestone of the Lower Cretaceous, the Upper Cretaceous formation in northern Mexico is characterized by its more shallow deposits of ferruginous limestones, clays, sands, and lignite all indicative of a more shallow origin than the purer lime beds of the main part of the lower series. The beds occur in the northeastern border States of Chihuahua, Coahuila, and Tamaulipas, and are at least 5000 feet thick; the complicated structure of the region does not permit the entire section to be measured in any one locality. The areal development of this formation is principally along the mountains composing the east front of the Cordilleran region between Presidio del Norte at the great bend of the Rio Grande and Tampico and along the margin of the plains adjoining them on the Atlantic side as shown in fig. 2. They are upturned in the mountain structure with the Lower Cretaceous limestones, but owing to their softer nature they are usually degraded from the summits down to the level of the plain where they occur as foot hills of the Sierra de Santa Rosa, Sierra Candella, Sierra Lampazos and other ranges. It is especially developed in the Rio Grande embayment between the great Balcones fault of Texas and the eastern front of the Coahuila Cordilleras. It continues northward in the structure of the Trans-Pecos mountains of Texas and New Mexico and in the Rocky Mountain system as the typical Upper Cretaceous and Laramie series of western United States. Eastward it continues as the Cretaceous and Eocene Lignitic formations of the southern coastal plain.

The subdivisions of this series, which as a whole is a continuous deposition, are not distinctly differentiated in this southwestern region; the deposits apparently represent the southwestern littoral of the great interior arm of the Atlantic in Upper Cretaceous time and do not extend across the Mexican peninsula to connect with the Pacific as did the Lower Cretaceous waters. The Dakota horizon has no true representative in the region, south of the 32nd parallel, but the Benton shales and clays with the typical *Inoceramus problematicus* and Scaphites occur near Juarez and in El Paso, Texas. The chalky beds of the Niobrara sub-epoch are also missing and the whole of the Niobrara-Pierre of the series is apparently represented by thinner ferruginous clays and impure limestones marked by a commingling of the characteristic fauna and the *Exogyra ponderosa* of the Southern States.

The Eagle Pass beds which White correlated upon good grounds with the Fox Hills stage have the characteristic aspects of that formation in northern Coahuila that they have in the Rocky Mountain region, and imperceptibly grade into the Laramie phase with its characteristic fauna. The latter, in

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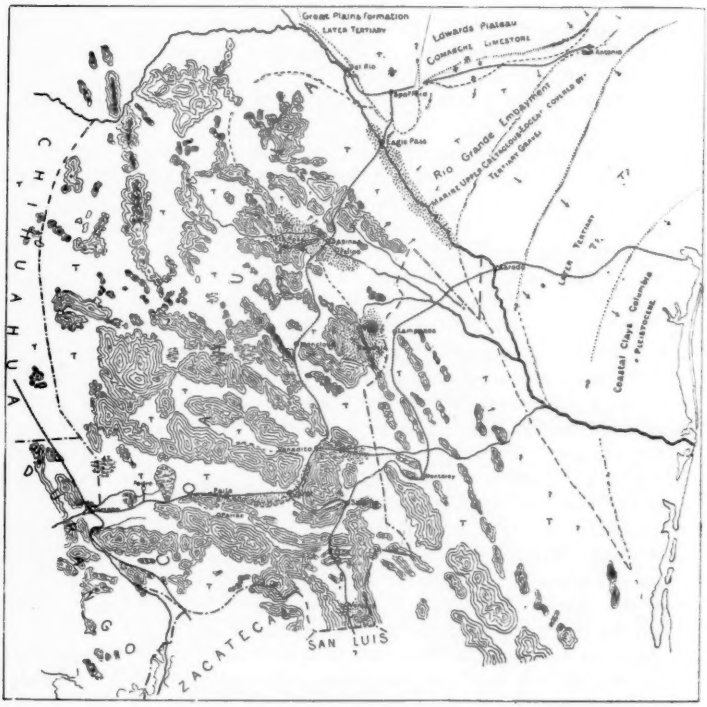


GEOLOGIC OUTLINE OF NORTHEASTERN MEXICO

Showing relation of Atlantic Coastal Plain, Cordilleran and Great Plains Region

BY

R. T. HILL

Topography modified from map by Mexican International Railway

turn, into the Eo-Lignitic beds of the Southern States, the whole having a unity of littoral lithologic features, thus indicating that the whole of the Upper Cretaceous and basal Eocene from the Dakota to the Claiborne inclusive, was a continuous epoch of sedimentation without any serious disturb-

ance of continuity until towards its close, and deposited at a marine base level now occupied by the eastern masses of the Rocky Mountains and eastern Sierra Madre.

None of the geologists—Schott, White, Penrose—or the writer, who have seen the continuous section of this formation exposed along the Rio Grande, from the unmistakable Ammonite horizon of the Cretaceous at Eagle Pass to the typical *Cardita planicosta* Claiborne Eocene horizon at Laredo, Mexico, have defined or recognized any distinct break in the continuity of sedimentation, but on the contrary every evidence of rapid estuarine or littoral deposition. In the midst of this section occur the fossiliferous horizons which White* has determined to be typical Laramie species, identical with those of the Colorado region. Some of these for instance, *Ostrea wyomingensis* Meek and *Anomia micronemia* Meek begin in the Ammonite-bearing Upper Cretaceous of Santa Rosa and Eagle Pass.

The Montana-Laramie Eocene portion of the formation occupies the vast synclinal basin of the Rio Grande, east of the great bend, which I have termed the Rio Grande Embayment, outcropping beneath the detrital deposits of late Tertiary and Pleistocene age. This synclinal is the contact of the Great Plains, Coastal Plains and Rocky Mountain regions as shown in fig. 3. The strata at the southern edge of the valley near Santa Rosa can be seen at the foot of the mountain upturned apparently conformably with the Comanche limestone which composes its mass, thus showing that the beds were involved in the great mountain movement of the east front of the Mexican Cordilleras. Likewise the strata of the Montana Laramie division are found across the front ranges of the Cordilleras, as shown upon the map, in the great enclosed intramountain basin between the Sierra Mercado of Monclova and the Sierra Candella, west of Lampazos, where three thousand feet of the strata occur in sub-vertical escarpments of hori-

4.

Cross section of the Sierra Candella west of Lampazos, Mexico, showing participation of Laramie strata in folding of the earlier Cordilleras. A, Intrusive Diorite. B, Comanche limestone. C, Laramie beds.

zontal or slightly dipping strata (see fig. 2). Around the edges of this synclinal basin the Laramie strata are again upturned as if they once extended over the mountain mass and

* This Journal, vol. xxv, 1883, p. 207.

contain the typical Laramie fauna of Corbiculidæ, *Ostrea wyomingensis*, and *Anomia micronemia*. Still southward, in another interior valley extending from Paderon—a village east of Venaditos—west to Jornos, the Montana-Laramie beds form similar foot hills against the interior border of the main mass of the Saltillo-Parras flank of the Eastern Sierra Madre.

On the east front of the Sierra Candella near Lampazos are two vast mesas of this formation—*Mesa Catahuana* and *Mesa Patrias*—the original Laramie localities where White first studied this formation in Mexico. It occurs thence southeastward as far as Tampico.

The participation of the strata of the Upper Cretaceous-Laramie series in the mountain movements of the eastern Cordilleras is further shown to the southward in the great Rinconada passes of the eastern Sierra Madre between Monterey and Saltillo where thousands of feet of the medial and lower beds of the series are folded in the mountain structure. The writer was not able to collect minutely from these beds but found many of the characteristic Inocerami and *Exogyra ponderosa* of the Upper Cretaceous showing the participation of the medial beds of the Upper Cretaceous in the movement as well as that of the Laramie.

While there is no doubt that there were some upland bodies of water upon the western continent during the Upper Cretaceous and Laramie epoch, especially during the emergence of the land in the latter part of the epoch, it can hardly be said that these sediments are fresh water deposits in the sense that they were not laid down at marine base level, for there is every evidence that the larger part of the Laramie and Upper Cretaceous deposits along the whole front of the eastern Cordilleran region both in the United States and in Mexico were laid down at marine base level adjacent to the great western continent that existed over the nucleal Cordilleran region at that time, and that the idea of one great enclosed Laramie inland sea must be abandoned.*

This Upper Cretaceous Eocene (Laramie) deposit undoubtedly represents the last littoral of the Atlantic along the eastern front of the older Cordilleran region prior to the last great folding, for none of the Claiborne Eocene fossils such as occur in the same series of sedimentation above the Laramie

* It is impossible here to discuss the Laramie question at length. Stanton and Cross in this Journal have both recently shown that several distinct formations have been confused under this name. In this paper the word is used to describe those sedimentations that insensibly succeed the last known beds containing unmistakable Cretaceous fossils and which like them were laid down at marine base level and containing estuarine, marine and fresh water fossils described by White and Meek under the name Laramie.

beds at Nuevo Laredo, are found in the folded mountain structure, as are those of immediately preceding beds, and it is probable that the age of the last folding of the Cordilleran eastern front can be accurately placed after the close of the Laramie, during the Eocene in Mexico, as it is in the Rocky Mountains. The movement no doubt began during the middle of the Upper Cretaceous, when an elevation of the shore line is indicated by the shallowing of the sediments, and was accelerated until the close of the Laramie, as is indicated in the enormous accumulation of littoral latest Cretaceous and Laramie sediments along the whole eastern half of the Rocky Mountain and eastern Sierra Madre region, finally culminating in the last great folding epoch immediately succeeding the latter time, thus completing the cycle of subsidence and elevation that took place between the Comanche, or mid Cretaceous and the Miocene. The waters of the arm of the Atlantic, or attenuated Gulf of Mexico receded from the present areas of the Great Plains for the last time, and the continental outline of to-day was practically defined.

How different is the land record of the Upper Cretaceous epoch from that of the Lower Cretaceous. It is true that during both periods the eastern margin of the continent again subsided and the waters of the ocean invaded large land areas; but the shore line of this Upper Cretaceous-Laramie was entirely different in the unstable Cordilleran region from that of the Comanche epoch. During the latter epoch it was the southern margin of the continent, or North American island, that subsided, but in Upper Cretaceous it was the Central or Great Plains region that went down, a great arm of the sea having extended inland between the Cordilleran and Appalachian lands, nearly severing our continent into two great islands, as has been shown by Prof. Dana, and culminated in the great littoral sedimentation of the Montana-Laramie epoch along the east front of the narrow land strip of the nucleal Cordilleran region. Nowhere in Mexico or the United States were the waters of the two oceans connected, and while the whole epoch was terminated in Eocene times by the last grand peripheral folding of the Cordilleras as seen in the Rocky Mountain front ranges from Montana to Mexico.

The accompanying table shows the sequence of the Cretaceous formations of Mexico, and their relations to those of the United States.

KNOWN POSITION OF THE CRETACEOUS AND RELATED FORMATIONS IN MEXICO.

Mexican occurrence.	Occurrence in United States.	Homotaxial Relations.
MIOCENE AND LATER. Detrital Upland deposits of Interior Basins and Cordilleran Slopes.	Genetically related to similar deposits of the Great Basin region, the Great Plains, and of the Texas Coast.	
EOCENE. Claiborne-Laramie beds of Nuevo Laredo, and Rio Grande Embayment.	Continuous on the American side of the Rio Grande.	Eocene and Transitional Cretaceous-Eocene, 7.
UPPER CRETACEOUS. Laramie-Montana beds of Eastern Cordilleras and enclosed basins of Coahuila.	Same as similar beds in Trans-Pecos, Texas, New Mexico, etc.	Transitional Cretaceous Eocene, and Senonian, 1, 2.
Beds at Juarez, and other points in Northern Chihuahua, Coahuila, and Carnero Pass, near Saltillo.	Continuation of Texas beds belonging to Colorado Division.	Turonian, 2, 4.
	(No beds of Dakota age have been recognized in Mexico.)	Cenomanian, 2, 3.
LOWER CRETACEOUS. Arivich, Juarez, and south of Tampico. Foothills of Santa Rosa and Monclova Mountains	Washita Division, Denison beds *c*. " " Fort Worth beds *b*.	Gault, (Albian) 6, *b*, *d*.
The so-called Hippurites Limestone of Mexico, together with adjacent barren limestones	Fredericksburg Division. Caprina limestone, and associated Comanche Peak beds.	Transitional and Upper, 6, *a*.
The Monopleura beds of Tehuacan, Bustamente, Topo Chico, etc.	Trinity Division, Glen Rose beds.	Middle, 6.
The Miquihuana beds, and alleged Jurassic of Catorce, San Luis, etc.	" " Trinity beds.	Lower, 6.
		Neocomian, 5, 6.

Authorities: 1, Sir Chas. Lyell; 2, F. B. Meek; 3, Leo Lesquereux; 4, F. Roemer; 5, Felix and Lenk; 6, the writer; 7, Dr. C. A. White. *a*, Senonian, Heilprin, Roemer. *b*, Neocomian, Marcou. *c*, Jurassic of Pyramid Mountain, Marcou. *d*, Cenomanian, Heilprin.

ART. XXXVIII.—*On Electrical Oscillations of Low Frequency and their Resonance;* by M. I. PUPIN, Ph.D., Columbia College.

Part I. *On the Production of Simple Harmonic Currents of Constant Frequency by Electrical Resonance.*

THE sensitiveness of the telephone for exceedingly small alternating currents is well known. It is probably as great as that of the most delicate Thomson galvanometer for direct currents. Just as this instrument, so the telephone is especially suited to zero-methods. But the telephone does not enjoy that popularity in the precision room which its direct current rival, the Thomson galvanometer, enjoys, although the field of physical research in which alternating currents must necessarily be employed is very extensive indeed. The fault lies with our alternating currents and not with the telephone. The alternating currents which the ordinary induction coil as employed in physical laboratories produces is far from being a simple harmonic current. The consequence is that in very many cases the zero method, for which the telephone is especially suited, has to be abandoned, and the minimum method substituted for it, which, of course, is a poor substitution.

Being engaged in a research in which I had to employ alternating currents I tried, for reasons just given, to devise some method of producing simple harmonic currents of constant frequency, the frequency to be easily and very accurately determinable. The following is my solution of this interesting problem:

A. *On the Production of Alternating Currents of Constant Easily and Accurately Determinable Frequency.*

My earliest solution of this problem consisted in producing an alternating current in the secondary of a very small transformer by making and breaking very rapidly and at a constant rate the primary. The interruptor of the primary current consisted of the following arrangement:

A stiff brass wire was stretched between the pole-pieces of a permanent horse-shoe magnet. The wire was supported, just as in a monochord, on two hard rubber bridges, and by varying the distance between the bridges and the tension of the wire it could be made to vibrate any note between about 60 and 1,000 complete vibrations per second. The middle part of the wire was between the pole pieces of the permanent magnet and carried just a short distance outside of the pole-pieces, a short, thin amalgamated copper wire which dipped into a mercury cup once during each vibration. At every dip it

closed the circuit of a gravity cell and the action of repulsion between the current now flowing through the stretched brass wire and the poles of the permanent magnet kept up the vibration of the wire when once started. In fact, when well adjusted the wire would start to vibrate of itself, making the primary current at every downward stroke and breaking it at every upward excursion. The current in the secondary was an alternating current, of course, of exactly the same frequency as the vibration of the wire. The frequency of the vibrating wire could be varied by varying the tension gradually until the vibration of the wire was in exact unison with a standard tuning fork. Varying the tension (in a manner which will be described below) of the brass wire did not interfere with its vibration, so that the tuning could be made very accurately by watching the beats. In this form, this what I call *electrodynamic interruptor*, was shown to Professors Abbe, Barker, Mendenhall, Michelson, and Rowland, during the autumn meeting of the National Academy of Sciences in New York, in 1891, and was very favorably commented upon by these scientists.

In the meantime experience suggested the form given in fig. 1, as best suited to the purpose for which the interruptor

Fig. 1.

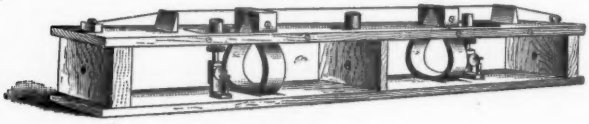
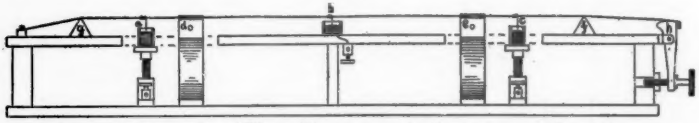


Fig. 2.



was first designed. The diagram of fig. 2 explains the construction of the apparatus more clearly. A stout aluminium, or phosphor-bronze wire, *the vibrator*, is stretched between the polepieces *d*, and *e*, of two permanent Weston magnets, such as this distinguished electrician uses in his voltmeters.

Fig. 3

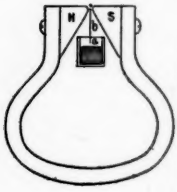


Fig. 3 gives the front view of one of the magnets. The cross section of the vibrator is seen there between the polepieces N S as a black dot. The short line, *a*, *b*, extending from the vibrator to the mercury cup below is the dipper, a short, thin amalgamated copper wire, which is soldered to the vibrator. The vibrator rests on two hard rubber bridges,

f, *g*. One of its ends is rigidly attached to the wooden frame of the apparatus, the other end is attached to a lever *h* which, worked by a micrometer screw, varies the tension of the vibrator. There are three mercury cups, *a*, *b*, *c*, and three dippers (which unfortunately do not appear in fig. 1). The middle cup, *c*, is fixed in position, and the middle dipper, being at the nodal point of the vibrator, makes a permanent contact there. The other two dippers make contact with mercury cups which can be raised or lowered by means of a nut and screw as represented in fig. 1, and indicated in diagram 2. The construction of the adjustable mercury cups and the stretching lever were copied from Dr. Max Wien's magnetic interruptor (Wiedem. Ann. 1891 and 1892). The middle cup (see fig. 4), is connected to one pole F, of the gravity or storage cell, the other two cups are connected one to one end, and the other to the other end of the primary of the small coil A, B. From the middle point, C, of the primary a wire leads to the other pole of the cell. Auxiliary small coils, E and D, and condensers, H and G, are inserted in the circuits as indicated. Their functions will be explained further below.

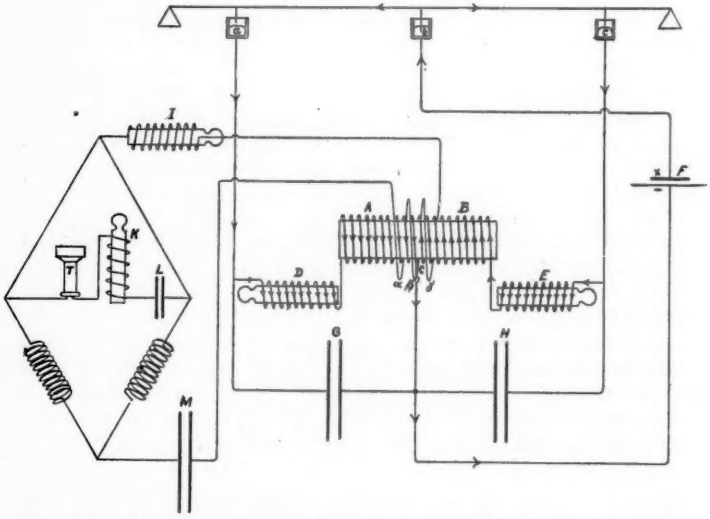
The vibrator vibrates with a node at the middle dipper as soon as the tension has reached a certain, by no means high, limit. A permanent contact is therefore maintained at this point, and the contact is made at one of the other cups just at about the same moment as it is broken at the other cup. Leaving the condensers out of consideration for the present, it is evident that this form of the current make-and-brake produces the same effect upon the iron core of the coil as an alternating current would. The advantage of this needs no comment; for although the iron core consists of the finest iron wire that can be obtained in the market, yet it must be remembered that the vibrator is expected to work sometimes at the rate of 512, or more, complete periods per second. Another immediate advantage which this interruptor offers is a considerable diminution of sparking. The addition of condensers, besides performing other functions which will be discussed presently, reduces the break sparks almost to invisibility, even when currents as large as half of an ampere are used. Each half of the primary coil consists of 532 turns of No. 22 silk-covered wire wound over an iron core of 30^{cm} in length, $4\,^{\square cm}$ in cross section, and consisting of very fine, soft iron wire.

The vibrator when at work gives a pure, but not objectionably loud, musical note in which the overtones are scarcely perceptible. The frequency ordinarily employed in my work is 256 complete periods per second, and it is obtained by bringing the vibrator in unison with a König standard tuning

fork. The tuning is done in a few seconds, without any difficulty, by simply stretching the vibrator gradually by means of the lever and micrometer screw and watching for the beats. The stretching does not interfere in the *slightest* with the vibrations of the vibrator.

The secondary current is, of course, an alternating current having the same frequency as the vibrator. But it is by no means a simple harmonic current. On the contrary, it is a very complex harmonic, its complexity depending on the fundamental frequency, on the ohmic resistances, and especially on the self-induction and electrostatic capacity of the primary and secondary circuits. A telephone placed in shunt with a part of the secondary circuit shows that without the condensers sparking is rather strong, producing that peculiar rattling noise which is full of those exceedingly high notes for which the telephone is especially sensitive. These high notes are due, as is well known, to rapid electrical oscillations which accompany the sparks. If the condensers are put in as indicated in fig. 4,

Fig. 4.



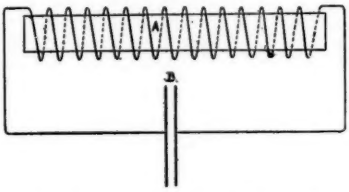
then the telephone shows that it is simply a question of capacity whether this or that overtone is particularly prominent. These overtones mean, of course, that in addition to the alternating current of the fundamental frequency there are also in the secondary circuit higher harmonic currents. In fact, the

telephone shows plainly that sometimes these upper harmonics are apparently much stronger than the fundamental current. The method of reducing the complex harmonic current obtained by the means just described forms the next part of this paper.

B. *On the method of weeding out harmonics by electrical resonance.*

If a coil, A, (fig. 5) is connected with a condenser B

Fig. 5



and an impulse starts an electrical disturbance in this system, then electrical oscillations will result from this disturbance. Electrical equilibrium is restored again after the electrokinetic energy produced by the impulse is partly radiated off and partly transformed into heat by the ohmic resistance of the circuit. Not to mention losses due to magnetic and dielectric hysteresis and to convection currents consisting of dust particles charged by contact with the systems. In Hertzian oscillations and in Tesla frequencies the period depends on the self-induction and the capacity of the system only, as is well known. But even in systems of large self-induction and large capacity, where *à priori* we can expect a long period of oscillation, this period can be easily shown to be independent of the ohmic resistance of the system in the majority of cases. An analytical discussion of this matter, as well as of other matters relating to resonance of slow oscillations is reserved for a future paper. Suffice it for the present to refer to these things, only in so far as they bear upon the subject of this paper.

The period of the system represented in fig. 5 is given (provided certain well-known conditions are fulfilled) by

$$T=\frac{2\pi}{10^5}\sqrt{LC}$$

where T is the period in seconds, L the coefficient of self-induction in Henrys, and C the capacity in microfarads. I shall refer to this period as the "*natural period*" of the system. By varying the capacity or the self-induction of the circuit we vary its natural period. I call this variation the *tuning of the electrical circuit.*

Let a complex harmonic, alternating electromotive force E act upon this circuit.

By Fourier's theorem E can be represented by

$$E = a_1 \sin pt + a_2 \sin 2pt + \ldots + a_n \sin npt + \ldots \text{ where } p = \frac{2\pi}{T}$$

T being the fundamental period. It is well to observe here that in complex harmonic e. m. forces as produced by ordinary methods the amplitude a_1, of the fundamental harmonic is largest and the amplitudes of higher harmonics diminish with the period of these harmonics.

The current produced in the circuit by the action of this complex e. m. f. will, of course, be a complex harmonic consisting of the same number of single harmonics as the e. m. f. and of the same periodicity; but the ratio of the amplitudes will be different now. The various simple harmonic components have also different phases. In general every one of these harmonics is a forced oscillation of the circuit, but by tuning the circuit we can bring it (within certain practical limits) in *resonance* with any one of the harmonics.

In my work I generally bring the circuits in resonance with the fundamental harmonic. A resonant circuit behaves toward a complex harmonic e. m. f. just the same as an acoustical resonator toward a source of complex sound. It brings out prominently that harmonic with which it is in resonance. To express this numerically, say that the ratio of the amplitude of the fundamental harmonic e. m. force to that of the next higher harmonic (supposing it even to be no higher than an octave) is 2 to 1. Then the circuit can be easily brought into resonance with the fundamental harmonic, in such a way as to increase the ratio of the amplitudes of the corresponding simple harmonic currents to 60 : 1. Theoretically (and to a great extent practically also) that ratio can be made anything we please by increasing continually the coefficient of self-induction and diminishing the capacity without destroying the resonance. In other words, we can by proper single tuning weed out the upper harmonics as much as we please. But, as will be indicated later on, it is not always advisable to avail ourselves too much of the means of weeding out the upper harmonics by using very large self-induction. The best method of tuning depends on the nature of the problem before us. I propose to discuss two cases, after stating briefly the experimental method which I consider as the simplest in detecting resonance. Consider the circuit represented in fig. 5. Put a telephone in shunt with some part of the circuit between the coil and the condenser; insert a small auxiliary coil with movable iron core in series with the large coil. Say the fundamental frequency

is 256 per second, make the condenser capacity larger and larger until the deepest note in the telephone (in our case 256), comes out strongest. It is easily recognized, for the difference between the sound of the telephone with the upper harmonics strongly represented and the sound without them, is just about the same as between the sound of a clarinet and that of a drum when playing the same note. Having done that, I then move the iron core of the auxiliary condenser until the telephone sounds loudest. The circuit is then in resonance with the fundamental harmonic.

An interesting phenomenon is observed during the first part of the tuning process. While plugging the condenser, so as to bring the capacity nearer and nearer to the point of resonance, a certain point is reached, when taking out a condenser plug is followed by a bright, snapping, spark. The spark is a sign that the point of resonance is very near, for resonance produces a difference of potential between the condenser plates which is many times higher than the amplitude of the impressed electromotive force. I proceed to consider this phenomenon a little more fully.

Case I.—Method of Tuning for the purpose of producing a high rise of potential at the Condenser plates.

When resonance is established the ratio of the amplitude E_o of the impressed e. m. f. to the amplitude $E_,$ of the difference of potential at the condenser plates is given by

$$\frac{E_,}{E_o}=\frac{10^6}{\frac{2\pi}{T}CR}.$$

Where C is the capacity of the condenser in micro-farads, R the resistance in ohms and T the period in seconds.

On the other hand,

$$T=\frac{2\pi}{10^6}\sqrt{LC}$$

Hence

$$\frac{E_,}{E_o}=\frac{2\pi L}{T R}.=\frac{\text{Inductance}}{\text{Resistance}}$$

If the priod $T=\frac{1}{400}$ and $E_o=5$ volts, then

$$E_,=\frac{2\pi\times 400\times L}{R}\times 5.$$

Hence to get the rise in potential as large as possible it is necessary to make the resistance as small, and the coefficient of self-induction as large as mechanical (and financial) considera-

tions will permit. It is not difficult at all to construct a coil whose L=5 and R=5, in which case $E_{/}$=over 12000 volts.

In a circuit of this kind the amplitude of the fundamental harmonic would be at least 2000 times as large as that of any of the upper harmonics. In other words, we should have a simple harmonic current in the circuit. In such a circuit the condenser has very small capacity and can be replaced by vacuum bulbs partially coated with tinfoil on the outside and electrical discharges could be produced in them by this enormous rise in potential. Hence the interest attached to this method of tuning. I expect to take up this interesting subject in another communication as soon as time will permit.

Case II.—Method of Tuning for the purpose of supplying a Wheatstone Bridge with a simple Harmonic Current of constant frequency.

In this case the method of tuning is governed somewhat by the well known conditions under which the flow in a Wheatstone bridge system will have the highest sensitiveness. These conditions exclude the possibility of using self-inductions which are very much larger than those in the principal branches of the bridge. *Two kinds of apparatus can be employed. The first* and in a great many respects the most convenient kind of apparatus is the interrupter described above. In this case the most difficult, but at the same time the most interesting part of the tuning consists in establishing resonance between the circuits ADGC, BCHE (fig. 4) and the vibrator. It is done in the following way:

The vibrator is first tuned up to any frequency we wish, say, 256, in the manner described above, all the iron having been previously removed from the coils and a high resistance inserted between F and C so as to reduce sparking at the dippers. The iron cores are then gradually pushed in and the capacity of the condensers G and H varied until the sparking is reduced to a minimum. This process is continued until the iron core of the principal coil AB is entirely in the coil. The final touches to this part of the tuning are given by means of shifting the iron cores of the small auxiliary coils D and E. By watching the sparks in the cups *a* and *c* the point of maximum resonance can be determined with great accuracy. For at this point the sparks are scarcely visible. If there is any defect in this adjustment it shows up immediately when the current is increased, by gradually diminishing and finally removing the resistance which, as a matter of precaution, was inserted in the circuit between F and C. The voltage of the generator F does not (within reasonable limit) seem to cause a

variation in the size of the sparks if the adjustment is properly done. I have used as much as four storage cells in series as my exciter and have no doubt that with a properly constructed vibrator as much as 100 volts could be used without any annoyance arising from the sparks. But the interruptor must be kept in a place entirely free from jars or vibrations. For even with the storage battery just mentioned, when the voltage is only 8 volts, vibrations of the floor or table or singing a note which is nearly in unison with the vibrator will disturb its vibrations sufficiently to cause a dissonance between the vibrator and the circuits. This dissonance manifests itself at once by lively sparking which subsides as soon as the disturbance ceases. It is this very state of extreme sensitiveness of the electrically tuned up system which makes the work with the vibrator exceedingly instructive and interesting.

The secondary coil $\alpha\beta\gamma$ (fig. 4) supplies the alternating current for the bridge. The number of its turns is small in comparison to the number of turns in the primary and the current in it is also small in comparison with the current in the primary, on account of comparatively high resistance in the bridge, so that the variation of the secondary current does not interfere with the established resonance in the primary. We can therefore tune this circuit without disturbing the adjustment of the primary. The tuning is performed by means of the auxiliary coil I, the condenser M, and a telephone placed in shunt with a part of the circuit whose resistance is high enough to give sufficiently intense sound in the telephone.

Finally, the bridge itself containing the telephone T is tuned by means of the auxiliary coil K and condenser L. This part of the tuning does not interfere with any of the previous adjustments on account of the extremely small value of the current which has to pass through the telephone to make the sound in it sufficiently intense.

It is needless to observe that the upper harmonics which the vibrator tends to produce are completely wiped out in the telephone circuit and that, therefore, with this arrangement we can employ the zero method of measurement, using as our detector the ordinary Bell telephone.

The second kind of apparatus that can be employed is a coil in series with a condenser as in fig. 5. A spark space is inserted in the circuit between the coil and the condenser and the extremities of this spark space are connected to the poles of an influence machine, or a high Voltage electromagnetic generator, and an air blast is applied to the spark space when the sparks begin to pass. An alternating current of any frequency may thus be generated in this coil-condenser circuit by a proper adjustment of capacity and self-induction and by gradual trans-

formation and tuning deprived of all its upper harmonics. This method is to be preferred when we wish to obtain a simple harmonic current of definite frequency to drive a synchronous alternating current motor, that is to say, a simple harmonic current, carrying with it a large quantity of power. I hope that I shall be pardoned for observing here that this last method was worked out by me some time ago. But in conversation with Mr. Nikola Tesla this distinguished experimentalist informed me that he obtained a patent about a year ago on the method of generating alternating currents of any frequency by means of disruptive discharges. The discovery that I was anticipated in a pretty invention caused me some disappointment at first, but I consoled myself very soon with the idea that a method patented by so excellent an experimentalist as Mr. Tesla, would enable me to obtain the object for which I invented it, the object being *to construct a synchronous alternating current motor which would spin around with great but perfectly constant angular velocity, the angular velocity to be just as adjustable and just as accurately determinable as the time of vibration of my vibrator, the motor to perform the function of a microphonograph.* I expect to be able to offer a favorable report on this matter very soon.

A communication of the results of some of my experiments with the simple harmonic currents obtained by the method described in this paper will be given as soon as time will permit.

Electrical Engineering Laboratory,
School of Mines, Columbia College, March 8th, 1893.

ART. XXXIX.—*On the Determination of Iodine in Haloid Salts by the Action of Arsenic Acid;* by F. A. GOOCH and P. E. BROWNING.

[Contributions from the Kent Chemical Laboratory of Yale College—XXI.]

THREE years ago we demonstrated* the possibility of determining iodine in mixtures of alkaline chlorides, bromides, and iodides, with rapidity and exactness, by taking advantage of the behavior of arsenic acid toward the haloid salts in presence of sulphuric acid of definite strength. We showed in brief, that when amounts of potassium iodide ranging from 0·005 grm. to 0·5 grm. were dissolved in 100 cm^3 of water containing 2 grm. dihydrogen potassium arseniate and 20 cm^3 of a mixture of sulphuric acid with water in equal volumes, the entire amount of iodine was expelled on boiling down the solu-

* This Journal, vol. xxxix, p. 188.

tion from 100 cm³ to 35 cm³; and further, that arsenic, reduced to the arsenious condition to an amount the exact equivalent of the iodine liberated, remained in solution and was determinable, after neutralization of the acid, in presence of an alkaline bicarbonate, by titration against standard iodine according to Mohr's classical method. We studied carefully the behavior of alkaline bromides and chlorides under identical conditions and determined that 0·5 grm. of potassium bromide acted upon the mixture of arseniate and acid to the extent of reducing arsenic equivalent to 0·0008 grm. of iodine, and that 0·5 grm. of sodium chloride did not reduce arsenic but did cause, under the conditions, a volatilization proportional to the amount of arsenious oxide present, the loss amounting at the most — when 0·56 grm. of the iodide was present to exert its reducing action upon the arsenic — to 0·0011 grm. We showed, furthermore, that these maximum errors, due to the action of bromides and chlorides, though not large and tending to neutralize one another when both bromides and chlorides are present, may be eliminated by the application of a numerical correction to the results whenever the amounts of bromide and chloride present become known.

Recently Messrs. Friedheim and Meyer* have recognized the value of our reaction and applied it to the elimination of iodine from mixtures of haloid salts. They have, however, taken issue with us (unadvisedly, as we think) as to matters of detail. They have, in the first place, put themselves upon record as being unable to titrate arsenious oxide by iodine in alkaline solution under the conditions of our process. They account for their failure by the wholly unsupported hypothesis that the iodine reaction is unavailable in presence of the amounts of salts present, and modify the treatment by distilling, collecting the iodine in the distillate, and determining it by the thiosulphate method, thus introducing complexity of apparatus and manipulation, and sacrificing the simplicity and rapidity which are chief advantages of our process. Had they read our paper with intelligent care it must have been evident that we had given special attention to the question of the influence of the salts present upon the iodine reaction; for we expressly stated that "due correction was made for the amount of iodine necessary to develop the test-color in a solution prepared and treated similarly in all respects to the experimental solutions excepting the introduction of the iodide—the correction amounting to a single drop more of the decinormal iodine than was required to produce the end reaction in the same volume of pure water containing only the starch indicator." It

* Zeitschr. f. Anorg. Chem., i, p. 407.

is obvious that such errors as 0·003 to 0·006 grm., which Messrs. Friedheim and Meyer found even in the absence of bromides and chlorides, are not explicable by the action of the salts which we used. Our errors ranged under like conditions from 0·0009 grm. − to 0·0003 grm. +, with a mean error in nine determinations of 0·0002 grm. −.

Everybody knows that the starch iodide test is most delicate in acid solutions and in presence of combined iodine, but Mohr's method of titrating arsenious oxide and iodine against one another in alkaline solution is sufficiently delicate for very exact work provided only that the alkali in excess is in the form of the bicarbonate, that the starch emulsion is used in abundance, and that the volumes of solutions titrated are regulated to low and uniform measure. In many determinations of iodine made by our method at different times and with different materials it has never been our ill-fortune to chance upon results so extraordinary as those of Messrs. Friedheim and Meyer, though we have met in the course of our work with potassium arseniate so contaminated with nitrates as to be unfit for use and with alkaline hydroxides too impure to employ. Most analytical processes depend for their exactness upon the use of proper materials: ours is no exception to the rule in this regard.

As to the correctness of the main reaction there appears to be no difference of opinion between Messrs. Friedheim and ourselves. We have, therefore, taken the pains, perhaps unnecessarily, to make experiments in which the estimation of the iodine of the same identical portions is effected both in the distillate and in the residue, in order that the two modes of estimation may be brought into direct comparison. It is scarcely needful to add that we took care to work with pure reagents. The potassium iodide, like that which we employed in our former investigation, was prepared by acting with resublimed iodine upon an excess of iron wire, pouring off the solution from the iron when the color of iodine had vanished, adding iodine equal to one-third the amount of that originally used, pouring the filtered liquid into a boiling solution of the calculated equivalent of potassium carbonate (from the bicarbonate), and filtering off the precipitated magnetic oxide of iron. The slightly alkaline solution thus made, containing approximately 2 grm. of potassium iodide in 100 cm³, and free from chlorine and bromine, was standardized by precipitating the iodine from weighed portions in the form of silver iodide and weighing upon asbestos. The other reagents—the sulphuric acid, the sodium hydroxide, the acid potassium carbonate, the dihydrogen potassium arseniate—when present in the proportions used in our process, and mixed with 5 cm³ of clear

starch solution prepared by Gastine's formula* (5 grm. starch, 0·01 HgI_2, 1 liter of water) gave the starch blue with a single drop of decinormal iodine at all dilutions below 300 cm³. The results of these experiments are given in the following table.

	Iodine taken in form of KI.	Iodine found in residue by our method.	Iodine found in distillate by As_2O_3.	Iodine found in distillate by $Na_2S_2O_3$.	Error in residue.	Error in distillate.
	grm.	grm.	grm.	grm.	grm.	grm.
(1)	0·4054	0·4052			0·0002 −	
(2)	0·4057	0·4055			0·0002 −	
(3)	0·4054	0·4052			0·0002 −	
(4)	0·4054	0·4052			0·0002 −	
(5)	0·4042	0·4046	0·4046		0·0004 +	0·0004 +
(6)	0·4050	0·4052	0·4040		0·0002 +	0·0010 −
(7)	0·4050	0·4052		0·4039	0·0002 +	0·0011 −
(8)	0·4058	0·4052		0·4051	0·0006 −	0·0007 −
(9)	0·4054	0·4046		0·4051	0·0008 −	0·0003 −
(10)	0·4042	0·4046		0·4039	0·0004 +	0·0003 −
(11)	0·4055	0·4052		0·4057	0·0003 −	0·0002 +

Experiments (1) to (4) were made exactly in accordance with the directions of our former paper, the mixtures being simply boiled in an Erlenmeyer flask trapped to prevent mechanical loss by hanging in the neck of the flask, with the larger end downward, a straight, two-bulbed drying tube cut off so as to leave the larger tube about 4 cm. in length. These four experiments all gave the same result, which differed from the theory by 0·0002 grm. −. The mixtures of the remaining experiments were treated in a flask connected with a cooled receiver and absorbtion tubes for condensing the distilled iodine (all joints being of glass and carefully ground) and carbon dioxide was passed through the apparatus in slow current to facilitate the transfer of iodine and quiet boiling. In experiments (5) and (6) the iodine was received in an alkaline solution of standard arsenious oxide and titration was effected with standard iodine after addition of starch. The residue was treated by our method. It will be observed that the residues, which contain the large amounts of salts, yield results by titration practically identical with those obtained by treating the distillates which do not contain the large masses of salts. In experiments (7) to (11) the iodine distilled was received in potassium iodide and estimated by standard sodium thiosulphate, itself standardized against the iodine whose value in terms of the standard arsenious oxide was also known. The residues were treated by our method. It is evident that the

* Bull. Soc. Chim., l, 172.

errors of both processes of treatment are reasonably small, (respectively 0·0001 grm. – and 0·0004 grm. – in the average) with what difference there is in favor of our treatment of the residues. Our process is incomparably the more convenient and rapid. We do not doubt that Messrs. Friedheim and Meyer could have obtained equally good results had they worked with pure reagents.

Messrs. Friedheim and Meyer disagree with us also as to the degree of concentration of the liquid necessary to insure the complete expulsion of iodine and as to the effect of the concentration upon bromides present—points to which we gave particular attention in our former paper. We showed that, in general, upon boiling a mixture of iodide with sulphuric acid and the arseniate diluted with water, the amount of iodine removed depended upon the proportion of the sulphuric acid to the final volume of the whole liquid, it being plainly shown that even after the liquid had lost the color of free iodine in the process of concentration it was still possible to detect combined iodine. Further concentration and, to some extent, dilution and repetition of the concentration to the former point tend to set free the residual iodine. In experimenting upon the proportions of acid most convenient for the work we found that a solution made up to contain 0·5 grm. of potassium iodide, 2 gram. of dihydrogen potassium arseniate, and 20 cm³ of the sulphuric acid mixture (1 : 1 by volume) retained when boiled down to 40 cm³ no determinable free iodine and but the faintest trace of combined iodine, while at 35 cm³ the liquid was free from iodine in any form. Upon experimenting as to the behavior of mixtures of chlorides and iodides we found that 0·5 grm. of sodium chloride added to the mixture containing 0·5 grm. of the iodide occasioned at 40 cm³ a maximum loss of arsenious chloride equivalent to 0·0004 grm. of the oxide, or to 0·0008 grm. at 30 cm³; and that the loss as a matter of course, is less as the amount of iodide present (and consequently the arsenious oxide formed) is diminished. We found that 0·5 grm. of potassium bromide treated in similar manner occasioned no loss of arsenious bromide but did induce at 35 cm³ reduction of the arsenic acid amounting to 0·0005 grm. of iodine. Smaller amounts of bromide produced proportionately smaller effects, but concentration even a little below 35 cm³ was likely to be productive of serious error. We fixed upon 35 cm³ therefore, as the ideal concentration for removing iodine from unknown mixtures with chlorides and bromides, but expressly stated that failure to concentrate below 40 cm³ introduces no appreciable error, while great care should be taken not to press the concentration below 35 cm³ on account of the

danger of bringing about the reduction of the arsenic by the bromide.

Messrs. Friedheim and Meyer contend that the reduction of volume under the conditions should not be pressed beyond 50 cm³ at the most, and cite in proof experiments in which potassium bromide in amounts less than half as great as those which we used caused an error on concentration to 35 cm³ equivalent to five or six milligrams of iodine. They recommend boiling from 150 cm³ to 50 cm³ to remove the iodine without disturbing bromine. Our former experiments are sufficiently definite upon these points. We have, however, determined directly and quantitatively the amounts of iodine remaining unexpelled when solutions are boiled from150 cm³ to 50 cm³ and found, in certain experiments, in which the additional iodine expelled in concentrating from 50 cm³ to 35 cm³ was collected in potassium iodide and estimated with sodium thiosulphate, that about 0·0013 grm. remained when 0·5 grm. of potassium iodide was originally taken, and 0·0003 grm. when 0·25 grm. of the iodide was present at the first. It is evident, therefore, that concentration to 50 cm³ is not sufficient when the maximum amount of iodide may be present. We have also made certain experiments—recorded below—in which the bromine liberated at different degrees of concentration was collected in potassium iodide and estimated by the iodine set free. In our former work we inferred the loss of bromine from the effects upon the arsenic acid in the residues. In these experiments solutions of potassium bromine (free from iodine), with 20 cm³ of sulphuric acid (1 : 1), and 2 grm. of dihydrogen potassium arseniate were boiled down in a flask connected by ground glass joints with a cooled receiver containing potassium iodide, or the iodine set free was estimated by standard sodium thiosulphate.

KBr taken. grm.	Initial volume. cm³.	Final volume. cm³.	Bromine in distillate. grm.
0·5	150	50	trace
	50	40	trace
	40	35	0·0004
0·5	50	31	0·0010
	31	26	0·0064
	26	23	0·0072
0·25	45	40	none
	40	31	0·0004
	31	27	0·0010
0·25	50	35	0·0003
0·1	50	30	0·0003

From these results, which confirm very closely those obtained by an examination of the residues and recorded in our former paper, it is evident that the concentration may go under the most unfavorable conditions—when the maximum amount of bromide is present—to 40 cm³ without loss and to 35 cm³ with small loss. As we stated in our former paper concentration below 35 cm³ should be avoided.

In our former paper we showed that the iodine could he determined in unknown mixtures of sodium chloride, potassium bromide, and potassium iodide taken in amounts not exceeding 1·5 grm. (in which, however, neither individual salt was present in amount exceeding 0·5 grm.) with a maximum error ranging from 0·0013 grm. − to 0·0016 grm. +. We showed, further, that when the amounts of chloride and bromide present were known also a correction for the action of these salts might be applied which reduced the maximum errors to 0·0010 grm. − and 0·0008 grm. +, and gave a mean error of 0·0001 grm. − for twenty-six determinations.

In conclusion we affirm the correctness of our former work and reiterate our former directions without change.

ART. XL.—*The Radiation and Absorption of Heat by Leaves;* by ALFRED GOLDSBOROUGH MAYER, M. E. (Stevens Institute of Technology.)

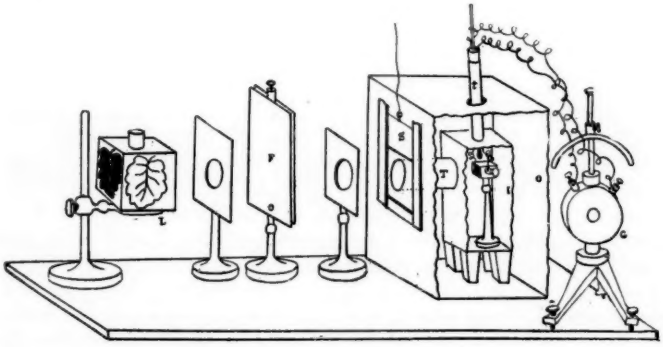
THE present research was commenced in the Physical Laboratory of the University of Kansas in the autumn of 1890, and continued in the Jefferson Physical Laboratory of Harvard University.

As plants must necessarily receive a considerable portion of their energy by the absorption of the sun's heat during the daytime, and then lose some of this heat by radiation during the night, it becomes of some interest to the physiological botanist to determine what may be the laws of this periodical gain and loss. Furthermore as by far the greater portion of the land surface of the globe is covered by vegetation, the laws of its radiation would become an important factor in a determination of the radiation of heat by the earth.

Apparatus.—In the research use was made of a highly sensitive thermopile in connection with a low resistance, reflecting astatic Thomson galvanometer. As it was feared that heating the leaves to abnormal temperatures might alter the coefficients of radiation of their surfaces, the form of apparatus shown in fig. 1 was devised, by means of which the radiation from leaves at the temperature of the air of the laboratory might

be determined. The essential parts consisted of two concentric boxes made of sheet tin (O I, fig. 1), drawn with their sides nearest the observer torn away in order to show the

Fig. 1.



internal parts. The two boxes were connected by means of the tin tube (T) soldered into a perforation in the middle of a side of each.

The inner box which contained the thermopile was mounted upon wooden legs, and running out from its top and also through the top of the larger box was the tube (*t*). The wires which connected the thermopile with the galvanometer (G), ran through this tube (*t*), as did also a very delicate thermometer giving the temperature of the air surrounding the thermopile. The sliding metallic screen (S) could be dropped down over the opening of the tube T, thus shielding the thermopile from all radiant heat. The capacity of the larger box was about 850 cubic inches, that of the inner one being 150. The outer box was jacketed with a two-inch layer of cotton wool.

By filling the space between the two concentric boxes with cracked ice, the temperature of the thermopile, and of the air in the inner box which surrounded it, could be lowered, so that one might determine the radiation from leaves at the temperature of the air of the laboratory. This apparatus possessed also the very great advantage that there were no air currents impinging upon the thermopile, and as a consequence its readings were remarkably concordant.

Many determinations both of radiation and absorption of heat were made by the aid of this apparatus, but in the excellent constant-temperature room of the Jefferson Physical Laboratory it was found unnecessary to inclose the thermopile, and therefore it was mounted upon an ordinary Melloni's bench.

Of course, as the thermopile was then at the temperature of the air of the room it became necessary to raise the temperature of the leaves which radiated to it. It was found, however, by numerous experiments, that the temperature of the leaves might be raised to 45° C. without altering in the least the coefficient of radiation from their surfaces.

Methods of Experimenting.

I. *Radiation of Leaves:*—Two leaves of the same species of plant and as nearly alike as possible were procured, and each was glued, flat, upon one of the polished tin sides of the Leslie cube (L, fig. 1). One of the leaves was then painted over with lampblack in alcohol, which caused it to present a dull, dead black appearance. The Leslie cube was then filled with water which was heated to about 40° C., at which temperature it was maintained constantly by means of a low luminous flame of a Bunsen burner. A side of the cube bearing a leaf was turned so as to face the thermopile, and after the temperature of the water had become steady, the falling screen (F, fig. 1) was lowered, the slider S raised, and the deflection of the galvanometer after five minutes exposure to the radiant heat carefully observed. An exactly similar experiment was then gone through with, upon the lampblacked leaf, in order that the radiation from the green leaf might be accurately compared with that from a similar surface of lampblack. Great care was taken in these experiments that the thermopile cooled completely, so as to cause the galvanometer to return to its zero reading before another experiment was performed. As the deflections of the galvanometer were small the radiation was assumed to be proportional to the deflection produced.

II. *The Effect of Dew upon the Radiation of Leaves.*—As a copious film of dew commonly forms upon the leaves of plants during summer nights, it occurred to me to ascertain whether their radiating ability was thereby altered to any perceptible degree.

The experiments were conducted as follows:—A leaf was glued to the polished side of the Leslie cube as in experiments upon radiation. The cube was then filled with finely cracked ice. This soon caused a film of dew to form upon the surface of the cooled leaf. The temperature of the air of the room and of the melting ice in the cube was then determined. The leaf was placed facing the thermopile, the shielding screens removed and the deflection of the galvanometer after five minutes exposure observed. The Leslie cube was then filled with water which was heated up and maintained at a tempera-

ture, as nearly as possible, as much *higher* than the temperature of the room as the melting ice was *lower* than that temperature. A five minute exposure was again given and the reading of the galvanometer taken. From the results of these two experiments it became possible to compare the radiation of the dewed leaf with the heated one. For example: let t_1 represent the temperature of the air of the room, supposed constant, t_0 that of the melting ice, T that of the heated water in the Leslie cube, d_0 the deflection produced by the dewed leaf, and d_1 that caused by the dry heated leaf. Then assuming the deflections of the galvanometer to be proportional to the radiation's we would have

$$(T-t_1):(t_1-t_0)=d_1:x$$

Instead of x coming out equal to d_0 as it would do if the coefficient of radiation of the dewed surface were equal to that of the heated surface, it was always greater than d_0; thus proving that the coefficient of radiation of the leaf was *lowered* by the dew which had collected upon it.

III. *Absorption of Heat by Leaves.*—In performing these experiments the side of the Leslie cube was lampblacked, and the cube filled with water which was kept gently boiling. The reading of the galvanometer produced by five minutes exposure to the hot lampblacked surface of the Leslie cube was taken and compared with that produced when the heat from the Leslie cube was obliged to pass through a leaf, placed over a diaphragm, between the cube and the thermopile. Great care was taken to insure that all the heat which reached the thermopile had passed through the leaf. From the results of these two experiments it became a simple matter of ratio to calculate the percentage of heat absorbed by the leaf. Thus: Let D be the deflection produced when the heat passed uninterruptedly from the cube to the thermopile, and d that produced when the path of the heat was intercepted by a leaf, placed between the cube and the thermopile. Then the percentage of heat transmitted by the leaf would evidently be given by the expression $\frac{d \times 100}{D}$ = per cent transmitted. To find the per cent absorbed we have merely to subtract the per cent transmitted from 100. By causing the heat to pass through successively, one, two, and three leaves placed in its path, some facts relative to the selective absorption of leaves were obtained. By determining the heat-absorbing ability of a fresh green leaf, and then dissolving out its chlorophyl in alcohol or ether and testing the same leaf again, it became possible to ascertain how much of the absorption was due to the chlorophyl of the leaf.

Results of the Experiments.

In conducting the experiments upon radiation it was deemed wise to select leaves of widely different genera of plants; accordingly the leaves of a few forest trees, bushes, weeds living in both sunny and shady places, aquatic plants, cultivated plants and grasses were chosen. The results of a series of experiments upon the following leaves demonstrated that the coefficient of radiation of dark heat from both their upper and lower surfaces was *exactly* the same as that of lampblack.

The leaves tested were elm, oak, maple, horse chestnut, basswood (*Tilia Americana*), silver poplar, beech, lilac, mullein (*Verbascum thapsus*), plantain (*P. major*), lilly pads (*Nuphar advena*), cultivated grape, blackberry and clover. A single interesting exception, however, was discovered. The upper surface of burdock leaves (*Arctium lappa*) radiates exactly as do all other leaves, but the *under* surface radiates only 81 per cent of this amount.

These leaves are very broad and thick, and as they lie for the most part spread out horizontally very near the ground, the under surface is largely shaded from the sun's rays, and therefore receives but little direct heat. Moreover it is probable that being so near to the ground less dew would form upon the under surface than upon the upper. Both of these causes would combine, as we shall see later, to make it very advantageous to such leaves to possess a poorly radiating lower surface.

Of course, as leaves radiate exactly as lampblacked surfaces, they also possess correspondingly good absorbing surfaces. Numerous experiments were made by the method already described to ascertain the effect of dew upon the radiation of leaves. If we call the radiation from a dry leaf 100, that from a leaf covered by a thin film of dew is about 78, and if the dew stand out in beads over the surface the radiation is reduced to 66.

A polished tin surface which only radiated 14 per cent as much heat as a lampblacked surface, radiated 96·8 per cent of the lampblacked one when both were covered with beads of dew. The coefficient of radiation of the lampblacked surface was lowered, and that of the polished one raised until the radiation was nearly the same from both. So potent is a film of dew in altering the nature of a radiating surface.

Upon the importance of this remarkable fact we need hardly dwell. The surface of leaves being one of the best known radiators of heat, is therefore an equally good absorber of that heat. If then we imagine a forest in the tropics where the days and nights are of almost equal length the whole year round, very much of that heat which had been absorbed by the leaves during the day, would be lost by their great radiation

during the night, were it not for the fact that the blanket of dew which covers them cuts down this radiation to two thirds of its former value.

In the experiments upon the absorption of heat by the leaves, considerable individual difference was found in different specimens of the same species of leaf. In stating the results therefore I shall give the range of variation, where necessary. The following table gives the percentages of heat absorbed and transmitted by single leaves of the species named.

Name of Leaf.	Transmits	Absorbs
Ash	19·7 per cent	80·3 per cent
Elm	18–23	77–82
Maple	16–20	80–84
Wild Cherry	15–18	82–85
Horse Chestnut	19	81
Lilac	14–18	82–86
Mullein (V. thapsus)	17	83
Burdock (A. lappa)	14	86
Chicory (Chicorium intybus)	17	83
Rose leaves	28–31	69–72
Petals of red rose (cultivated)	33	67
" " White rose	27	73
" " Yellow rose	24	76
" " Oenothera speciosa	28	73
" " Tradescantia Virginica	31	69

The above table would seem to indicate that if dark heat be allowed to pass through a leaf, rather more than 80 per cent is absorbed by the leaf and somewhat less than 20 per cent transmitted. The heat passes through exactly as readily when it enters by the lower surface, as when it enters the upper.

The absorption of heat by leaves is highly selective. Thus a single elm leaf in the path of the dark radiant heat transmits 20 per cent of the heat which entered it. If now the heat which has passed through the first leaf be allowed to fall upon a second, it will be found that only 78 per cent of it will be transmitted. A third leaf will transmit over 83 per cent of the heat which passed through the second, and the effect of a fourth leaf is hardly noticeable. This may in some measure account for the somewhat remarkable fact that there is no very great difference between the absorbing abilities of such leaves as mullein and wild cherry, although the former are thick tough leaves and the latter very thin. By dissolving the chlorophyl out of leaves and again testing them, as has been explained under methods of experimenting, it was found that this substance absorbs but little of the dark heat. Thus, wild cherry leaves transmitted 9· per cent and chicory (*C. intybus.*)

4· per cent more heat when their chlorophyl was abstracted by ether or alcohol. In thick tough leaves such as lilac or elm, however, I was unable to detect its influence. It will be seen upon referring to the table that rather more heat seemed to be transmitted by the petals of flowers than by leaves. Natural selection has forced all leaves to the optimum as regards transmission and absorption of heat, and hence we find but little difference in the behavior of leaves of widely different genera of plants in this respect. Their surfaces have become the best known absorbers of heat, and in order to counterbalance the consequent disadvantage of being the best of radiators, the dew, which collects upon them at night, cuts that radiation down.

In conclusion, it gives me pleasure to acknowledge my great indebtedness to Professor Trowbridge, who kindly placed at my disposal the excellent apparatus and facilities of the Jefferson Physical Laboratory.

Cambridge, October, 1892.

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SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On an improved Boiling-point apparatus for determining Molecular Masses.*—Three effects are now made use of for determining molecular masses; (1) the decrease of vapor-pressure, (2) the lowering of the freezing point, and (3) the raising of the boiling point, of a solvent by dissolving in it the substance to be examined. Sakurai has devised a simple and valuable modification of the apparatus described by Beckmann for determining the molecular mass of a substance by the elevation of the boiling point which a known quantity of it produces when dissolved in a known quantity of the solvent. The boiling vessel is a U tube of glass about 2^{cm} in internal diameter and 21^{cm} in height. Near the top of one of the legs is a lateral tube for attaching a

Liebig's condenser. An ordinary round bottom flask, placed by its side, is closed with a cork through which passes the stem of a tap-funnel and also a delivery tube. By means of a thick rubber tube, the end of this delivery tube is connected to the end of a similar tube passing through the cork of one of the legs of the U tube and terminating at its lowest part. Through a cork closing the other opening of the U tube, the thermometer passes. This reads to hundredths of a degree. The flask is surrounded with a tin plate vessel and the U tube with a box made of asbestus cardboard. To make an observation, the delivery tube is fixed in the U tube, and the bent portion of this tube is filled with glass beads. The solvent is now introduced till it rises 3 or 4^{cm} above the beads, and the thermometer is put in place. The flask, half filled with the same solvent, is then connected with the delivery tube and both it and the boiling vessel are heated by carefully regulated lamps. When the liquid in both vessels begins to boil, the tap in the funnel is closed and that connecting with the condenser is opened, and the boiling is continued for fifteen minutes or more. Then the thermometer is read by means of a telescope. The substance is introduced into the boiling tube by removing the thermometer, and the boiling point of the solution is determined again in the same manner. The thermometer used by the author read to hundredths, but by the telescope thousandths of a degree could be estimated. The device of the accessory flask enables the temperature to be made constant even to this limit. Results are given in which the solvents used were water, alcohol, ether, and carbon disulphide; and in which the substances dissolved were mercuric chloride, mannite, cane sugar, acetanilide, salicylic acid, naphthalene, iodine and sulphur. The molecular mass was calculated from the formula $m = B \times g/\Delta$ in which m is the molecular mass sought, B a constant depending on the solvent, g the mass of the substance dissolved in 100 grams of the solvent, and Δ the observed rise of the boiling point. B has the value $0{\cdot}02T^2/W$, where T is the absolute temperature and W the heat of vaporization of one gram of the solvent. In the case of water B has the value 5·2, alcohol the value 11·5, ether 21·0 and carbon disulphide 24·0. With respect to iodine the author finds its molecular mass in CS_2 from 247 to 261, and in ether from 255 to 261; thus confirming Beckmann's conclusion that its molecular magnitude is the same in both solutions. For sulphur in CS_2 the author finds the values 252 to 254; also confirming Beckmann as to the existence of a complex molecule consisting of S_8.—*Jour. Chem. Soc.*, lxi, 989, December, 1892.

G. F. B.

2. *On the color of the Ions.*—An investigation has been made by OSTWALD on the absorption spectra of the solutions of several series of colored salts not only by measuring the position of the bands but also by photographing the whole spectrum. It appears from the results obtained that the spectra of dilute solutions of salts having the same colored ion are identical. In the case of

the permanganates for example, solutions containing the molecular mass in grams of the ion MnO_4 in 500 liters of water, give the same values for the absorption bands whatever the base. On the arbitrary scale employed, the four bands of potassium permanganate for example, were at 2600, 2697, 2803 and 2913; the positions of these bands in the twelve other permanganates examined not differing more than two or three units from these. In further proof of the fact that with this degree of dilution the metallic permanganates are completely dissociated, photographic reproductions of the several spectra are given side by side, in the paper, these spectra being identical for the different salts employed. The same conclusion was found to be true of the salts of fluorescein with sodium, lithium, benzylamine, potassium, methylamine, ammonia, piperidine, dipropylamine and trimethylamine; and also of the salts of eosin, both blue and yellow, of iodeosin, of dinitrofluorescein, of orcinphthalein and its tetrabromine derivative, of rosolic acid, of diazoresocin, of diazoresorufin, of safrosin and of the chromoxalates. To show that the law is equally true for positive ions as for negative the author gives the results obtained with the salts of para-rosaniline, anilineviolet, chrysaniline and chrysoidine, twenty different non-colored acids being employed. Generalizing from 300 cases examined the author regards the fact as established, that in dilute solutions, salts having the same colored ion give identical absorption spectra; the few exceptions being readily accounted for, either by the formation of insoluble compounds or by the hydrolysis of salts having feeble acids or bases.—*Zeitschr. physik. Chem.*, ix, 579; *J. Chem. Soc.*, lxii, 1137, Oct. 1892. G. F. B.

3. *Affinity-coefficients of Acids.*—The relative affinities of a number of acids have been measured by LELLMANN and SCHLIEMANN by means of a spectrophotometric method. This method is as follows: A measured quantity (25^{cc}) of a solution of two milligram-equivalents (0·448 grms.) of pure metahydroxyanthraquinone in a liter of 96 per cent alcohol, is mixed with a definite quantity of a solution of known strength of the pure barium salt of the acid, the mixture diluted to 50^{cc} and examined with the spectrophotometer; its absorption being compared with that of a solution of the same quantity of metahydroxyanthraquinone in excess of barium hydroxide. The alcohol and the water used in the preparation of the solutions are both carefully purified from basic substances by distillation over potassium hydrogen sulphate and even the glass vessels in which the solutions are kept are carefully freed from alkali by prolonged digestion with dilute sulphuric acid. In cases where the barium salt is not sufficiently soluble the potassium salt is employed. The results are given in terms of a constant k; this constant expressing the fact that when in the alcohol-mixture employed, equal equivalents of metahydroxyanthraquinone, of a given acid and of the base are contained, and when k equivalents of the salt of the acid are formed to one of a salt of metahydroxyanthraquinone, this fact

may be briefly expressed by saying that the acid is k times stronger than the metahydroxyanthraquinone. The value of k for formic acid for example is given as 61·97; of acetic acid 14·33; of benzoic acid 20·71; paramidobenzoic acid 7·60; lactic acid 39·94; propionic acid 11·68. The results obtained, even within very wide limits of concentration, are completely in agreement with the law of Guldberg and Waage; but they cannot be brought to accord with Ostwald's values of the affinity constants as determined by the electrical method, even when the same solvents are employed in the two cases. The authors regard the affinity coefficients as determined by the spectrophotometer method as expressing more simply and directly than can be done by the dissociation constants, the relation which exists between chemical change and the nature of the inter-acting substances.—*Ann. Chem. Pharm.*, cclxx, 204, 208; *J. Chem. Soc.*, lxii, 1269, November, 1892. G. F. B.

4. *On the Reaction of Hydrogen with Chlorine and Oxygen.*—Some time ago, in conjunction with Dixon, HARKER showed that contrary to the prevalent impression, hydrogen, when exploded with oxygen and excess of chlorine, does not unite wholly with the chlorine, but that water is formed at the same time. These experiments were left incomplete and Harker has now continued them with a view to determine whether the ordinary laws of mass action hold in this case. Much difficulty was encountered at first in carrying out the experiments, and special apparatus was devised for the purpose which is fully described in the paper. In all 18 experiments were made, in which the volume of chlorine added to 50 volumes of hydrogen and 50 volumes of oxygen varied from 9·08 to 95·83. The results show that in all cases a division of the hydrogen between the chlorine and the oxygen takes place. Moreover, this division takes place in such a way that the product of the number of molecules of hydrogen chloride and of those of oxygen divided by the product of the number of molecules of water vapor and of those of chlorine is practically constant, the mean value of this constant as given by the experiments being 23. The law of mass action laid down by Guldberg and Waage holds therefore in this as in other cases.—*Zeitschr. physik. Chem.*, ix, 673; *J. Soc. Chem.*, lxii, 1147, Oct., 1892. G. F. B.

5. *On the daily variation of Gravity.*—Professor MASCART, for several years has employed a barometric tube with a column of mercury four meters and a half in length, which counterbalances the pressure of a mass of hydrogen contained in a lateral vessel. The whole apparatus is sunk in the ground with the exception of a short column of mercury at the top. The level of the liquid is compared with a lateral division, the image of which is formed in the axis of the tube, and the points may be fixed to within the $\frac{1}{100}$ of a millimeter. The curves of variation present a very regular and slow course, due to changes of temperature, but on some days certain perturbations arise the duration of which is from

fifteen minutes to an hour. These do not seem explicable otherwise than by correlated variations of gravity. These perturbations often exceed $\frac{1}{20}$ of a millimeter. They seem to be undoubted and the author is arranging an apparatus constructed with great care for further observations.—*Phil. Mag.*, March 1893; *Comptes Rendus*, January 30, 1893. J. T.

6. *Simple apparatus for the determination of the Mechanical Equivalent of Heat.*—C. CHRISTIANSEN describes with figures a simple apparatus for the determination of this important constant. Two trials gave J=42900, J=43060. The cost of the apparatus is 175 marks.—*Ann. der Physik und Chemie*, No. 2, 1893, pp. 374–376. J. T.

7. *On a certain Asymmetry in Concave Gratings.*—Dr. J. R. RYDBERG discusses this subject and explains the asymmetry observed. Since the two sides of the gratings often give spectra of different brightness, the author believes that one can conclude that the furrows which the point of the diamond makes in the reflecting surface are not symmetrical in section. This explanation is not insisted upon, but is merely given as a possible explanation. The adjustments for getting rid of asymmetry are given in detail.—*Phil. Mag.*, March, 1893, pp. 190–199. J. T.

8. *Potential of Electric Charges.* — Various investigations differ widely in their measures of the charge on spheres raised to different potentials. A. HEYDNEILER reviews the subject and appends a table in C. G. S. units which gives the charge on spherical electrodes of various radii, at variable distances apart of these electrodes.—*Ann. der Physik und Chemie*, No. 2, 1893, pp. 213–235. J. T.

9. *Sensitive Galvanometer.* — H. E. J. G. DUBOIS and H. RUBENS describe a new form of astatic galvanometer which they believe excels other forms. Taking the nomenclature and classification recommended by Ayrton, Mather and Sumpner, (Phil. Mag., xxx, p. 58, 1890), current sensitiveness S_c is the deflection in scale divisions per micro-ampere, distance of scale being 2000 divisions and the full period of swing being 10 seconds.

The ballistic sensitiveness S_b is the deflection in scale divisions per micro-coulomb, distance of scale being 2000 divisions. The period of swing being 10 seconds with light suspensions. Ayrton's table gives as the highest value S_c=413. The authors obtain a value of S_c=800. Tables of the ballistic sensitiveness are appended.—*Ann. der Physik und Chemie*, No. 2, 1893, pp. 236–251. J. T.

10. *Experiments with Currents of High Frequency.*—A. A. CAMPBELL SWINTON states that he has succeeded in passing through his body sufficient electricity to bring the filament of an ordinary 5 candle-power 100-volt incandescent lamp very nearly to full incandescence or to bring the filament of a 32 candle-power 100-volt lamp to full redness. No sensation was experienced. The apparatus consisted of an Apps coil, the primary of which was supplied with a powerful make-and-break current. The secondary

of the Apps coil included a step-up transformer constructed on the principle of those described by Mr. Tesla. The author thinks that the assumption that high frequency currents are harmless by reason of their high frequency is not correct. The true reason being the extremely small amount of current which accompanies the high voltage.—*Phil. Mag.*, February, 1893, pp. 142–145.

J. T.

II. Geology.

1. *Correlation Papers—Neocene* (*Bulletin of the U. S. Geological Survey, No.* 84, *Washington*, 1892); by William Healey Dall and Gilbert Denison Harris.—A part of the recent work of the Geological Survey in the classification of the formations of the United States for the purpose of constructing a general geologic map is represented by a series of memoirs showing the present state of our knowledge of the several systems of rocks, in America, the series being called "Correlation Papers." The memoirs represent not only bibliographic study but more or less field work. That pertaining to the Neocene (including the Pliocene and Miocene of the Lyellian classification) is especially rich in results of original field researches in both invertebrate paleontology and stratigraphy. The treatment of Florida and Alaska in particular is monographic, and so largely based on the personal observations of the senior author as to render the memoir the best source of information extant concerning the geology of these little known corners of our domain.

The Neocene formations of the country are considered as belonging to three natural geographic provinces, viz: the Atlantic and Gulf province, the Pacific coast province, and an interior province made up of terrestrial and freshwater basins. The principles of classification recognized are far-reaching and philosophic. In the first place, the deposits are classified by genesis as (1) marine sediments, (2) perizonal deposits (the deposits accumulated "between the neutral zone where sediments are dropped" by the sea "and the point where subaërial erosion terminates"—page 98), (3) lake beds, and (4) subaërial and fluvial deposits. These several classes of deposits are regarded as dynamic types. Proceeding on the basis of this physical classification, the applications and limitations of paleontologic correlation are next set forth. It is first shown that deposits of different dynamic types may be synchronous, as the life conditions are sometimes so diverse that synchrony can neither be assumed nor denied *à priori*. Then the more general conditions affecting deposition and organic existence are discussed, and it is shown that the distribution of fossils and thus the correlation of fossiliferous formations is affected by various conditions, notably sea-temperature. From a census of the shell-bearing marine mollusks in recent faunas of different temperature zones throughout the world, the authors "conclude that that part of the average mollusk fauna which is

capable of leaving traces in the shape of fossils, under conditions not greatly different from those of the present day, if situated in the arctic or boreal region, would comprise about 250 species; in the cool temperate region about 400 species; in the warm temperate, about 500 species; and in the tropical region, not less than 600 species" (page 27). The clear recognition of these local and general conditions as affecting the life of the globe prepares the way for a distinct advance in practical geologic correlation. Many years ago Barrande developed the conception of colonies, and subsequently Huxley wrought out the idea of homotaxis to explain the recurrence of allied faunas in different regions at different periods; and in this country Calvin, followed in greater detail by H. S. Williams, called attention to the changes in Paleozoic faunas evidently accompanying changes in character of sedimentation. These paleontologic researches, in common with modern researches in biology, show that life has not flowed in an even stream but has been constantly affected by local and general environmental conditions. Dall and Harris go further than their paleontologic predecessors and, thanks to the exceptional opportunity afforded by the study of relatively recent deposits, are able clearly to formulate a part at least of the homotaxial conditions. Thus their memoir is an important contribution not only to geology through paleontological method but also to general biology, and may be considered an exposition of the principles of homotaxy. The authors' final conclusion concerning the applications and limitations of paleontology as a basis for geological correlation is thus stated: "While paleontology holds the key to the problems of local and comparative stratigraphy, yet no study of paleontology that neglects the broad and general stratigraphic changes which accompany the development of the continental border as a whole is calculated to afford results of permanent value" (page 31).

The second chapter is a summary of knowledge concerning the Neocene of the Atlantic and Gulf coasts, arranged by states and illustrated by a special map of Florida and a general map showing the distribution of the Neocene formations of the country; while the third chapter is a general discussion of the relations of the Neocene deposits of the eastern province.

After showing that the Pliocene of North America, though homotaxial is probably not wholly synchronous with that of Europe and that the end of the American Miocene as generally understood, was marked by a great movement in elevation which united North and South America and joined the island of Florida to the mainland of Georgia, the authors adopt the culmination of this elevation as the physical event terminating the Miocene and from which the American Pliocene extends until, in its turn, terminated by the inauguration of the Glacial epoch.

Having thus limited the major divisions of the Neocene, the subdivisions of Miocene and Pliocene are discussed. The term Miocene in the United States has hitherto been understood to include the epoch covering the deposition of the well known

beds extending from New Jersey to Georgia which have been variously subdivided by Heilprin and others. It is now shown, however, that this Miocene, for which the name Chesapeake is adopted, represents only a part of the geological column between the Eocene and Pliocene. It was preceded by a division of at least equal importance, represented on the Gulf coasts by a greater thickness of strata, which encloses a fauna closely related to the Haitian and Jamaican Miocene, and of a distinctly tropical facies. Traces of this fauna are found in New Jersey, but it is in Florida and on the north shores of the Gulf of Mexico that it is found, uneroded, in its full development.

For the epoch covering its deposition and including the Chattahoochee and Tampa groups the name of Chipola has been proposed by Dall in a later publication.* The transition from the Chipola to the Chesapeake fauna is abrupt and is shown to involve a marked refrigeration of the Gulf of Mexico.†

The Pliocene of Florida shows a subtropical reaction in the matter of temperature, perhaps promoted by the closure of the strait which in Miocene times separated the peninsula from Georgia. The age of the South American fossil mammals which are found in Florida is determined by their discovery, as announced here, between mid-Pliocene shell limestones; and, incidentally, the peninsula of Florida is shown to consist of a central trough or ancient lake-basin, for which the name of De Soto is proposed, with low but unmistakable parallel folds on either side of the peninsula. The entire peninsula is built up of marine organic sediments and contains no minerals of other origin. Degradation has proceeded by solution rather than erosion, and reasons are given for supposing that the peninsula, since the Miocene, has maintained a remarkable stability and has not submitted to any serious changes of level.

Two chapters are devoted respectively to detailed description and general discussion of the Neocene formations of the Pacific coast of the United States and Canada, including Alaska; the latter being illustrated and elucidated by a convenient "Table indicating conditions existing during Cenozoic time in regard to changes of level" and the prevalence of volcanic emissions on the northwest coast (p. 278). The most interesting fact discussed is the age of the so-called Miocene leaf-beds of Alaska and the northwest coast which may probably turn out to be of Eocene age. The "Ground ice formation" of northern Alaska has also a peculiar interest.

* Trans. Wagner Inst., vol. iii, p 307, Jan., 1892.

† This writing gives opportunity for the correction of an erroneous expression by the writer, printed before the appearance of the above memoir ("The Lafayette Formation," 12th Annual Report of the Director of the U. S. Geological Survey, 1892, page 411). The faunal change recognized by Dall and Harris has no connection with differences made by Heilprin the basis of a separation of the Atlantic coast Miocene into a "Marylandian" and "Virginian" series. The latter simply relate to proposed subdivisions of the Chesapeake formation, on the principle of percentages of survival.

The formations of the interior province, over 30 in number, are described in detail by states and correlated so far as the data permit by paleontologic characters coupled with dynamic conditions. The memoir is supplemented by an "Annotated list of names applied to Cenozoic beds and formations of the United States excluding the Laramie (pages 320–338), over 200 in number."

The work is slightly marred by clerical and typographical errors due to the absence of the authors while the matter was passing through the press; several of these are noted in a list of errata, but others may be noted by readers—e. g. the statement on page 189 that the Lafayette formation reaches "a *thickness* of 450 to 550 feet" should read "altitude." It should also be noted that nearly two years intervened between the submission and publication of the manuscript. W. J. McGEE.

2. *Michigan Geological Survey—Report of the State Board of Geological Survey for the years* 1891 and 1892. 192 pp. 8vo, 1893. Lansing, Michigan.—Contains the Reports of Dr. CARL ROMINGER for the years 1881–2 and 1882–3; of Mr. CHARLES E. WRIGHT for the years 1885–8; of Dr. M. E. WADSWORTH for the years 1889, 1890, 1891, 1892, made to the State Board of Geological Survey for the years named; and also a Provisional Report by Dr. M. E. WADSWORTH, State Geologist, upon the Geology of the iron, gold and copper districts of Michigan.

3. *Geological Survey of Missouri*, ARTHUR WINSLOW State Geologist. Vol. II, 1892. *A report of the Iron Ores of Missouri*, by FRANK L. NASON, Assistant Geologist, for the years 1891 and 1892, 365 pp. 8vo, with maps, sections and other illustrations, 1892. Jefferson City, Mo.

Vol. III, 1892, 256 pp.—*A Report on the Mineral Waters of Missouri*, by PAUL SCHWEITZER, Assistant Geologist, embodying also the notes and results of the analyses of A. E. WOODWARD, Assistant Geologist, for 1890 and 1892. Jefferson City, 1892.

4. *Geological Survey of Texas*, 1892.—*Report on the Brown Coal or Lignite of Texas*, by E. T. DUMBLE, State Geologist, 232 pp. 8vo, with maps and other illustrations. Austin, 1892.

5. *The Journal of Geology:* A semi-quarterly Magazine of Geology and related Sciences. Vol. I, No. 1, pp. 1–112, January-February, 1893. The University Press of Chicago.—This new Journal opens with an interesting series of articles presented in particularly attractive typographical form; it promises to occupy a sphere of wide usefulness and influence. It is under able management: the senior editor is Professor T. C. Chamberlin of the University of Chicago, and the other editors are: R. D. Salisbury in geographic Geology; J. P. Iddings in Petrology; R. A. F. Penrose, Jr., in economic Geology; C. R. Van Hise in Pre-Cambrian Geology; C. D. Walcott in Paleontologic Geology; W. H. Holmes in Archeologic Geology. There are also thirteen associate editors, six of these chosen from abroad.

The table of contents of this first number is as follows: The Pre-Cambrian rocks of the British Isles, by Sir Archibald Geikie; Are there traces of glacial man in the Trenton gravels? by W. H. Holmes; Geology as a part of the college curriculum, by H. S. Williams; The nature of the englacial drift of the Mississippi basin, by T. C. Chamberlin. The subscription price is three dollars per annum.

6. *Republication of Conrad's Works.*—Conrad's "Fossil Shells of the Tertiary Formations of North America" will be republished by Mr. G. D. Harris of Washington, D. C., as soon as 100 subscriptions can be obtained at $3.00 each, (about half the original cost of publication). The new edition will include Nos. 1, 2, 3 and 4 of the original edition, No. 3 of the so-called "republication of 1835," together with the different editions of Prefaces, Introductions, etc. Those desiring copies at the above rate should confer at once with Mr. Harris, care of Smithsonian Institution.

Conrad's "Medial Tertiary" is about to be republished by the Wagner Free Institute of Sciences of Philadelphia.

7. *Lines of Structure in Meteorites.*—Dr. Brezina has kindly called my attention to the discussion of the lines in stony meteorites given by v. Reichenbach in an article in *Poggendorff's Annalen*, vol. cviii, pp. 291–311 (1859), *Ueber das Gefüge der Stein-Meteoriten.* H. A. N.

III. Botany.

1. *The localization of the perfumes of Flowers.*—Mesnard's method of examining floral odors is applicable to a wide range of micro-chemical studies. A ring of glass is cemented to a suitable glass-slide, and within this cell another smaller ring is glued, in such a manner as to leave between the two a clear annular space. In this space is placed pure chlorhydric acid. On a cover-glass, large enough to cover the whole of the larger cell, is put a drop of pure glycerine containing a good deal of sugar, and in this reagent is deposited the section of petal to be studied. The cover-glass is now to be inverted and applied to the outer ring. By the concurrent action of the vapor of the acid and the dehydrating activity of the glycerine, the essential or the fatty oil containing the perfume separates in minute drops.

A modification of the process directs that the central ring be covered by its own cover-glass. On this the drop of glycerine is to be put, and this is to hold the sections.

By this simple method, the localization of the perfume of the jasmine, rose, violet and tuberose, has been effected. G. L. G.

2. *Botanical Prizes of the French Academy.*—For the year 1892, these prizes were assigned as follows: The *Prix Desmazières*, for the most useful work published during the preceding year, on any cryptogamic subject was given to Professor Pierre Viala, for his studies in regard to certain diseases of grapevines and fruit trees. The committee call particular attention to the

thoroughness with which these pathological researches have been conducted, and to the long period of nine years which they have covered. The *Prix Montagne*, for local cryptogamic floras, has been given to Auguste-Marie Hue, an Abbé, for his Lichens of of Canisy, (Manche) and neighborhood. A second prize, of five hundred francs, was awarded to Dr. F. Xavier Gillot for his catalogue of the higher fungi of the neighborhood of Autun. The *Prix de la Fons Mélicocq*, for the best work on the flora of the north of France, is given to M. Masclef for his Geographical Botany of Northern France. The latter work was submitted in manuscript. The *Prix Thore* was not assigned. G. L. G.

3. *How blanched seedlings can be saved.*—Cornu communicates to the French Academy some very interesting notes in relation to a new method of bringing plants from distant tropical regions. The seeds of the plants in question are brought under conditions which reduce the chance of their germination during the voyage down to the smallest risk, but in spite of all precautions such seeds are likely to sprout and arrive as blanched, unhealthy and "drawn" seedlings which have hitherto been thrown away. Cornu has employed as a suitable mechanical support for the scanty roots of these unhealthy seedlings, a material known as fern-earth, that is, the detritus formed by the broken up rootstocks of *Polypodium vulgare*. This is a dry and somewhat porous mass which is almost free from any likelihood of any invasion by mould. Upon this polypod support, the isolated plants are placed with a little moisture, and are exposed to a small amount of light under a bell-jar. In a short time they resume their proper green color, and speedily take good root, after which they can be heaped up with common earth, or transplanted, as is thought best. By use of this simple means, it has been possible to save some very important plants which arrived at Paris in a wretched condition.

Not only are etiolated seedlings saved in this way, but it has been found possible to save also seedlings which have been injured by drying of some part or by mechanical injury. In some instances it has been the good fortune of Cornu to restore seedlings which had sprouted under soil and had come to hand in a perfectly hopeless condition.

The material which Cornu suggests is even better than coir, which has been employed for much the same purpose and in the same way. Coir is the firm fibre which surrounds the shell of the cocoanut, and which can be easily broken up into soft masses which are not at all affected by mould until a long time has elapsed. G. L. G.

4. *Influence of moisture on Vegetation.*—E. Gain (Comptes rendus, Nov. 21, 1892), has conducted experiments, which, though largely repetitions of investigations by others, are worthy of mention as showing a possibility of getting results from cultivation in an arid climate, under irrigation, which are unattainable elsewhere. Gain points out that a dry air and a moist soil are

very favorable to the blooming of plants, while a moist atmosphere is extremely unfavorable. This favorable effect was indicated in the former case especially by the precocity of the vegetation, which was so great as to allow of having three crops produced in a single season. From the researches of Gain, it would appear as if irrigation had advantages which have not hitherto been fully appreciated. G. L. G.

IV. Astronomy.

1. *Transactions of the Astr. Observatory of Yale University*, vol. i, Parts III and IV.

Part III. *Triangulation of Stars in the Vicinity of the North Pole;* by William L. Elkin.

This investigation was undertaken in consequence of a request from Prof. Pickering, of Harvard, to determine with the heliometer the relative positions of a few stars near the North Pole to serve as fundamental points for a photographic survey of that region. The author enlarged the plan to include 24 stars, nearly all of those bright enough to be well measured with the instrument within $1\frac{3}{4}$ degrees of the Pole in 1888. The plan of measurement adopted consisted in measuring all the intermutual distances between the 24 stars within the range of the heliometer, 145 of all the 276 possible combinations. These were observed each three times and a zone of stars ending with 51 *Hev. Cophei* and δ *Ursae minoris* was taken for an independent and simultaneous determination of the scale value. The adjustment of the measurement was carried out by a series of successive approximations, the system or coördiuates used being that proposed by Fabritius, which offers great advantages for stars near the Pole. A first set of approximations revealed the existence of a systematic error in the measures, which being duly allowed for, a final system was derived, which was referred to the Pole by means of the Berlin Jahrbuch places of α and λ *Ursae minoris*. These final places are also given in the usual system of right ascension and declination together with tables for precessional changes. The probable errors were derived by a process suggested by Dr. Gill. The proper motions of the stars are small; approximate values can be inferred from the comparison given with Carrington's places for 1855.

Part IV. *Determination of the Orbit of the Comet* 1847, VI, by Margaretta Palmer.

This comet was discovered on Oct. 1, 1847, by Miss Maria Mitchell at Nantucket, Mass., and subsequently independently by de Vico at Rome, by Dawes in England, and by Madame Rümker at Hamburg. Its orbit had been investigated by Dr. George Rümker in a nearly exhaustive manner, but a slight improvement seemed possible by a new discussion of the places of the comparison stars, by introducing modern places of the sun and by taking the planetary perturbations into consideration. This, together

with the personal incentive derived from the fact of the authoress's having been a pupil of Miss Mitchell at Vassar College, led to her undertaking a new determination.

Starting from Rümker's elements all the observations are compared with them, using star places derived from all available sources including the unpublished zones of the Astron. Gesellschaft, and taking into consideration as far as possible the systematic errors of the various authorities. The perturbations by Venus, the Earth, Mars and Jupiter are applied to the normal places which are obtained by using places of the sun from Leverrier's tables. The differential coefficients for the 6 normal places are computed by Schönfeld's formula and the normal equations are solved both for a parabola and an indeterminate conic section. In this latter case the eccentricity comes out = 1·0001727, indicating a hyperbolic character of the orbit. The reduction of the sums of the squares of the residuals from 702·11 for the parabola to 171·87 for the hyperbola makes the conclusion seem well warranted that the observational data require this latter curve for their satisfactory representation, thus confirming Rümker's similar conclusion.

2. *Schreiner's Spectral-Analyse Der Gestirne.*—It is announced that a translation by Prof. E. B. Frost of Dartmouth College, of Dr. Schreiner's well known work, is to be issued in the autumn of 1893. Subscriptions ($5) are solicited by the publishers, Messrs. Ginn & Co., Boston.

V. Miscellaneous Scientific Intelligence.

1. *Observations in the West Indies;* by Alexander Agassiz. (In a letter to J. D. Dana, dated Steam Yacht "Wild Duck," Nassau, March, 1893).—Here we are back at Nassau for the third time, and thinking you might be interested to hear of my cruises, I send you a short sketch of our trip. The first time we left Nassau we entered the Bahama Bank at Douglass Channel and crossed the Bank to North Eleuthera, where we examined the "Glass Window" and the northern extremity of Eleuthera, we then sailed along the west shore of the island close enough to get a good view of its characteristics as far as Rock Harbor at the southern end. We steamed out into Exuma Sound through the Beach Channel and round the southern end of Eleuthera to little San Salvador, and the northwest end of Cat Island, where are the highest hills of the Bahamas. We then skirted Cat Island along its western face, rounded the southern extremity and made for Riding Rocks on the western side of Watling's Island. We circumnavigated Watling, passed over to Rum Cay, then to northern part of Long Island, visiting Clarence Harbor; next we crossed to Fortune Island, and passed to the east side near the northern end of the island on the Crooked Island Bank. From there we crossed to Caicos Bank, crossing that bank from French Cay to Long Island, passed by Cuklum Harbor and ended our

eastern route at Turk Island; from there we shaped our course to Santiago de Cuba to coal and provision the yacht. We were fortunate enough to strike Cape Maysi a short time after daylight, and I thus had a capital chance to observe the magnificent elevated terraces (coral reef) which skirt the whole of the southern shore of Cuba from Cape Maysi to Cape Cruz and make so prominent a part of the landscape as seen from the sea. We were never more than 3 miles from shore and had ample opportunity to trace the course of some of the terraces as far as Santiago, and to note the great changes in the aspect of the shores as we passed westward due to the greater denudation and erosion of the limestone hills and terraces to the west of Cape Maysi, which seems to be the only point where five terraces are distinctly to be seen. The height of the hills back of Pt. Canete where the terraces are most clearly defined, I should estimate at 900 to 1000 feet; though the hills behind the terraces, which judging from their faces are also limestone, reach a somewhat greater height, perhaps 1100–1200 feet.

After coaling at Santiago de Cuba we visited Freayna, and next steamed to Hogstey Reef, a regular horseshoe-shaped atoll with two small Keys at the western entrance. There we passed three days studying the atoll. This to me was an entirely novel experience; to be at anchor in 3 fathoms of water 45 miles from any land with water 900 fathoms within 3 miles outside, surrounded by a wall of heavy breakers pounding upon the narrow annular reef which sheltered us. I made some soundings of the lagoon and of the slope of reef outside. From there we returned to Crooked Island Bank to the westward of which I also made some soundings to determine the slope of the Bank. We next again visited Long Island, taking in the southern and northern ends which I had not examined. From there we passed to Great Exuma, stopping at Great Exuma Harbor and sounding into deep water on our way out to Conch Cut when we sailed west crossing the Bank to Green Cay. From there we made the southward of New Providence, and before going in to Nassau Harbor made some trials in deep water in the Tongue of the Ocean with the "Tanner" deep-sea townet in 100 and 300 fathoms, depth being 700 fathoms—after which we returned to Nassau. I had on board a Tanner sounding machine kindly loaned me for this trip by Col. McDonald of the Fish Commission, and some deep-sea thermometers were also kindly supplied by him and by Professor Mendenhall, the superintendent of the U. S. Coast Survey. I supplied myself with a number of Tanner deap-sea townets and with a supply of drops and of townets and carried on board a Yale and Towne patent winch for winding the wire rope which I used in my dredging and towing in deep water. The yacht was provided with a steam capstan and by increasing its diameter with logging we found no difficulty in hauling in our wire rope at the rate of 8 min. to a 100 fathoms. I carried 600 fathoms of steel wire dredging rope with me

of the same dimensions which I had used on the "Blake" and which has also been adopted on the "Albatross." During our second cruise we steamed from Nassau for Harvey Cay crossing the Bank from north to south to Flamingo Cay and then to Great Ragged Cay, from which we took our departure for Baracoa. At Baracoa I hoped to be able to ascend the Yomque; unfortunately I had to give up my trip owing to the desperate condition of the roads. From Baracoa we steamed close to the shores to the westward, touching at Port Banes, Port Padre, Cay Confiles, Sagua, Cay Frances, Cardenas, Matanzas, and finally ending at Havana. This trip was a continuation of the observations we made on the south coast of Cuba and enabled me to trace the gradual disappearance of the terraces from Baracoa to Neuvitas, and their reappearance from Matanzas to Havana, from the same causes which evidently influenced their state of preservation from Cape Maysi west. I also got a pretty clear idea of the mode of formation of the fine harbors found on the northern coast of Cuba to the eastward of Neuvitas, and of the mode of formation of the extensive system of cays reaching from Neuvitas to Cardenas and which find their parellel on the south coast of Cuba from Cape Cruz to Cape Corrientes. After refitting at Havana we left for Nassau. Both on going into Havana and on leaving we spent the greater part of a day in towing with Tanner net. I thought I could not select a better spot for finally settling the vertical distribution of pelagic life than off Havana which is in deep water—900 fathoms—close to land, on the track of a great oceanic current, the Gulf Stream, noted for the mass of pelagic life it carries along its course. We towed in 100, 150, 250, and 300 fathoms and on the surface at or near the same locality, and I have found nothing to cause me to change the views which I expressed in my Preliminary Reports of the "Albatross" expedition of 1891. Nowhere did I find anything which was not at some time found also at the surface. At 100 fathoms the amount of animal life was much less than in the belt from 100 fathoms to the surface. At 150 fathoms there was still less and at 250 fathoms and 300 fathoms the closed part of the Tanner contained *nothing*. At each one of these depths we towed fully as long as was required to bring the net to the surface again. Thus we insured before the messenger was sent to close the lower part of the bar as long a pull through water as the open part of the net would have to travel till it reached the surface, giving the fauna of a horizontal column of water at 100, 150, 250 and 300 fathoms of the same or greater length than the vertical column to the surface for comparison of their respective richness. From Havana we steamed to Cay Sal Bank, visited Cay Sal, Double headed Shot Cays, Anguila Islands, and then crossed over to the Great Bank to the west of Andros Island. The bottom of this bank is of a most uniform level, 3 and 3½ fathoms for miles and then very gradually sloping to the west shore of Andros, so that we had to anchor nearly six miles from the wide opening of the central part of Andros which we visited. The

bottom consists of a white marl, resembling when brought up in the dredge newly mixed plaster of Paris, and having about its consistency just as it begins to set. This same bottom extends to the shore; and the land itself, which is low where we went on shore not more than 10 to 15 inches above high water mark, is made up of the same material, which feels under foot as if one were treading upon a sheet of soft india rubber; of course on shore the marl is drier and has the consistency of very thick dough. It appears to be made up of the same material as the æolian rocks of the rest of the Bahamas, only that it has become thoroughly saturated with salt water and in that condition it crumbles readily and is then triturated into fine impalpable powder almost like deep sea ooze which covers the bottom of the immence bank to the west of Andros. After leaving Andros we crossed the Bank again to Orange Cay and followed the eastern edge of the Gulf Stream to see Riding Rocks, Guin Cay and the Beminis. We then passed to Great Isaac where we saw some huge masses of æolian rocks which had been thrown up along the slope of the cay about 80 fathoms from high water mark to a height of 20 feet. One of these masses was $15' 6'' \times 11'' \times 6'$. We then kept on to Great Stirrup Cay coasting along the Berry Cays, crossed over to Morgan's Bluff, on eastward of Andros down to Mastic Point on the same Sound, and then returned to Nassau.

The islands of the Bahamas (as far as Turks Island) are all of æolian origin. They were formed at a time when the Banks up to the 10-fathom line must have been practically one huge irregularly shaped mass of low land, from the beaches of which successive ranges of low hills, such as we still find in New Providence, must have originated. After the islands were thus raised there was an extensive gradual subsidence which can be estimated at about 300 feet, and during this subsidence the sea has little by little eaten away the æolian lands, leaving only here and there narrow strips of lands in the shape of the present islands. Inagua and Little Inagua are still in the original condition in which I imagine such banks as the Crooked Island Banks, Caicos Banks and other parts of the Bahamas to have been; while the process of disintegration going on at the western side of Andros shows still a broad island which will in time leave only the narrow eastern strip of higher land (æolian hills) on the western edge of the tongue of the ocean. Such is the structure also of Salt Cay Bank which owes its present shape to the same conditions as those which have given the Bahamas their present configuration. My reason for assigning a subsidence of 300 feet is the depth of some of the deep holes which I have surveyed on the Bank and which I take to be submarine blow holes or cañons in the æolian limestone of the Bahama hills when they were at a greater elevation than now. This subsidence explains satisfactorily the cause of the present configuration of the Bahamas, but teaches us nothing in regard to the substratum upon which the Bahamas were built. The present reefs form indeed but an insignificant part of the to-

pography of the islands and have taken only a secondary part in filling here and there a bight or a cove with more modern reef rock, thrown up against the shores so as to form a coral reef beach such as we find in the Florida Reef. I have steamed now nearly 3,300 miles among the Bahamas, visiting all the more important points and have made an extensive collection of the rocks of the group.

I hoped to have made also a larger number of deep soundings than I have been able to take; unfortunately the trades were unusually heavy during the greater part of my visit to the Bahamas, greatly interfering with such work on a vessel no larger than the "Wild Duck"—127 feet on the water line. For the same reason the number of deep-water pelagic hauls was also much smaller than I hoped to make, as in a heavy sea the apparatus would have been greatly endangered. It is a very different thing to work at sea in a small yacht like the "Wild Duck," or in such vessels as the "Blake" and the "Albatross" of large size and fitted up with every possible requirement for deep sea work. The "Wild Duck," on the other hand, was admirably adapted for cruising on the Bahama Banks, her light draught enabling her to go to every point of interest and to cross and recross the Banks where a larger vessel could not follow. I am under the greatest obligations to my friend Mr. John M. Forbes for having so kindly placed his yacht at my disposal for this exploration, and I hope soon after my return to Cambridge to publish more in detail the results of this examination of the structure of the Bahamas.

2. *The Barrier Reef of Australia: Its Products and Potentialities;* by W. SAVILLE-KENT. (W. H. Allen & Co., 13 Waterloo Place, London.)—The publishers announce that this important work is now about ready. The specimen copies of the plates furnished give a high idea of the unusual beauty of the illustrations.

3. *Logarithmic Tables,* by Prof. GEORGE WILLIAM JONES of Cornell University. Fourth edition, 160 pp. 8vo. London (Macmillan & Co.) and Ithaca (George W. Jones).—There are many books of logarithmic tables, but this one is especially notable for its convenience and compactness of arrangement, clearness of typographical work and breadth of scope. Eighteen tables in all are given and the judicious selection and arrangement of these by the editor gives the student a much wider and more generous equipment for his work than can often be found within the limits of a small volume and one sold at the low price of seventy-five cents.

OBITUARY.

NICOLAS KOKSHAROV, the veteran and long honored Russian mineralogist, died on January 2, 1893, at an advanced age. His *Materialien zur Mineralogie Russlands,* of which the first volume was issued in 1853–54 and the tenth volume completed in 1891, is a monumental contribution to science and will always be a model of careful and accurate research.